AL.2.1985-93I
#2

ERCB D 84-28

JAN - 8 1985

ERCB

A Report on an Application by Canterra Energy Ltd. to Drill a Critical Sour Well in the Sundre Area

December 1984

DON

ERCB

A Report on an Application by Canterra Energy Ltd. to Drill a Critical Sour Well in the Sundre Area

December 1984

ENERGY RESOURCES CONSERVATION BOARD
DECISION REPORT

Report D 84-28 published December 1984

Published by:
Energy Resources Conservation Board
640 Fifth Avenue SW
Calgary, Alberta
T2P 3G4

Telephone (403) 297-8311

Telex 03-832717

Price: $5.00

CONTENTS

		Page
1	DECISION SUMMARY	1
2	APPLICATION	2
3	INTERVENTIONS	2
4	HEARING	2
5	PRELIMINARY MATTERS	5
6	BASIS FOR MAKING THE DECISION	5
7	PURPOSE OF THE WELL AND THE NECESSITY THAT IT BE LOCATED AS PROPOSED BY CANTERRA	6
8	MAXIMUM POTENTIAL H_2S RELEASE RATE	7
9	PRECAUTIONS TO BE TAKEN DURING DRILLING AND THE CHANCES OF A BLOWOUT – NON-CRITICAL WELL SECTION	9
10	PRECAUTIONS TO BE TAKEN DURING DRILLING AND THE CHANCES OF A BLOWOUT – CRITICAL SECTION	11
	10.1 Geological Prognosis	11
	10.2 Casing Design and its Impact on the Critical Section	11
	10.3 Drilling Equipment	12
	10.3.1 Blowout Preventers and Associated Equipment	12
	10.3.2 Mud-Conditioning Equipment	13
	10.3.3 Drill Pipe	14
	10.3.4 Kick-Detection Equipment	14
	10.3.5 H_2S Trim Equipment	15
	10.4 Safety Equipment	15
	10.5 Supervisory and Other Personnel	16
	10.6 Drilling and Kick-Control Procedures	16
	10.7 Detailed Drilling Plans	18
	10.8 Role of ERCB Field Staff if Well Licence is Issued	18
	10.9 Chances of a Blowout at the Proposed Well	19
11	ACTIONS TO BE TAKEN IN CASE OF A BLOWOUT AND THE RESULTING IMPACTS	20
	11.1 Actions to be Taken	20
	11.2 Plans for Capping Well	25
	11.3 Impacts of a Blowout	25
	11.4 Summary Views	29
12	TEST PHASES AND LIKELIHOOD OF FURTHER DEVELOPMENT	29
	12.1 Testing	29
	12.2 Likelihood of Further Development	29
13	FINDINGS	30
14	DECISION	32

APPENDICES

		Page
Appendix 1	Glossary of Terms	35
Appendix 2	Area Map, Figure 1	45
Appendix 3	Geological Cross-Section	47
Appendix 4	Resident Map, Figure 2	49
Appendix 5	Draft Interim Directive (Phase 2 – Lodgepole)	51
Appendix 6	Well Ignition Criteria	57

ENERGY RESOURCES CONSERVATION BOARD

Calgary Alberta

APPLICATION BY CANTERRA ENERGY LTD. TO DRILL A CRITICAL SOUR WELL IN THE SUNDRE AREA

Decision D 84-28
Application 830495

1 DECISION SUMMARY

This first section of the report provides concise comment on the application, public hearing, and decision of the Energy Resources Conservation Board (Board) for a proposed sour gas well in the Bergen area south of Sundre. This was a complex proceeding and the body of the report details the Board's consideration of the issues raised. This summary cannot convey the depth of consideration given to all the issues, and the interested reader is invited to review the summary of evidence and the "Views of the Board" respecting each of the issues and culminating in the findings and decision.

In August of 1984, the Board convened the first public hearing of a potentially high release rate critical sour well since the Lodgepole blowout inquiry Phase 2 report[1] (Lodgepole Phase 2 report) was issued.

The May 1983 application by Canterra Energy Ltd. (Canterra) proposed drilling a well in the Sundre area that could encounter high concentrations of hydrogen sulphide (H_2S), thus classifying the proposed well as a "critical well" as defined in the Draft Interim Directive attached as Appendix 5 of this report.

Earlier in the year, residents of the surrounding area had expressed great concern and asked for additional time to study and understand the proposal by Canterra. The public hearing originally scheduled for June was deferred until August to allow technical experts representing the Bergen Ratepayers Association (Bergen Group) and others to complete their review of the application.

Through the course of the hearing there was considerable discussion of the potential release rate of H_2S, drilling safety, public safety, and the ignition criteria for firing the well should there be an uncontrolled release of gas. The body of the report outlines the details of these topics, which the Board reviewed from the perspective that if there were no demonstrated need for the well, the matter would end right there and, even if the need were demonstrated, the safety of the public would remain paramount. Furthermore, even it if could be shown that an uncontrolled release of gas was unlikely, the Board would examine the consequences of an uncontrolled release to determine whether public safety could be maintained.

As set out in its findings in section 13 of the report, after reviewing all the evidence and taking into consideration the added precautions that must be taken as a result of the Lodgepole Phase 2 report, and the additional equipment and procedures as outlined by Canterra, the Board is satisfied that the probability of an uncontrolled release can be made acceptably low if the most up-to-date procedures and precautions are maintained. In this case, "acceptably low" means that the probability of an uncontrolled release is judged to be low enough to make it unlikely that residents of the area would have to endure an evacuation and other inconveniences. Notwithstanding that every effort would be made to avoid an uncontrolled release, the Board believes satisfactory measures can and must be in place to ensure public safety if a release should occur. Thus, ignition criteria and other safety measures would be essential and, as discussed in the report, the Board believes these measures could adequately protect the public.

Having concluded that Canterra has established a need for the well, and that public safety can be maintained, the Board is prepared to issue a well licence to the applicant, subject to conditions outlined in this report that are stringent and designed to ensure not only a low probability of an uncontrolled release, but also public safety in the event that a release does occur.

2 APPLICATION

Canterra applied pursuant to the Oil and Gas Conservation Act (the Act) for a licence to drill a well in legal subdivision 12 of section 12, township 32, range 6, west of the 5th meridian (the proposed 12-12 well). Canterra stated that the purpose of the well would be to evaluate and obtain production from the Leduc Formation. Canterra anticipated that if the target formation is penetrated, the reservoir could potentially contain sour natural gas with an H_2S content of 90 per cent. A potential H_2S release rate of 3.85 cubic metres per second (m^3/s) was estimated

[1] Decision D 84-5, Lodgepole Blowout Inquiry – Phase 2. Sour Gas Well Blowouts In Alberta; Their Causes, and Actions Required to Minimize Their Future Occurrence.

by the applicant which would result in a Level 3 facility as defined in Interim Directive ID 81-3[2]. No liquid hydrocarbons are anticipated.

The attached map (Appendix 2) shows the proposed well-site location relative to several nearby communities and other geographical landmarks.

The well was designated a critical sour well as defined in the Draft Interim Directive attached to the Lodgepole Phase 2 report. The Draft Interim Directive is included as Appendix 5.

Included in the application was information pertaining to geology, potential release rate determination, the proposed drilling program, post drilling operations, and a proposed emergency response plan. The proposed drilling program section included information on drilling time, casing and cementing details, blowout prevention (BOP) equipment, drilling fluids, and well-site personnel. It is important to note, however, that the submitted program did not contain all the details referred to in the Draft Interim Directive. Canterra took the position that if the requested well licence was issued it would submit more detailed information to satisfy Special Requirements 1 to 5 of the directive.

The application indicated that if a well licence was obtained and a successful well completed, the possibility existed that from 12 to 15 more wells could be required to produce reserves in the area. The drilling of these wells would likely lead to the construction of a field battery[3] facility and pipelines to transport the products to the Ram River gas plant. Canterra stated that applications to drill the wells and build the facilities, as well as an application to perform a production test on the 12-12 well, if licensed and successfully drilled, would have to be submitted to the Board and may be the subject of future hearings.

3 INTERVENTIONS

The Board received a number of interventions from community groups, individuals, and local municipalities in the area, many of which opposed the drilling of the well. Interveners questioned the need to drill a sour gas well at this time since considerable stockpiles of sulphur presently exist in the province. The interveners stated that the economic gains made by the applicant, and by the province as a whole through royalties, did not outweigh the value of the land and the contributions the farmers of the area made to the province through crops and livestock raising.

It was the general belief of the interveners that there was no previous experience, by the applicant or any other company, in drilling and eventually producing a well with 90 per cent H_2S content gas. Considering the untested technology to be used, the interveners classified the well as experimental, and it was their opinion that such a densely populated rural area was not the proper place to be proving the technology.

The qualifications of the on-site supervisors and the training procedures to be used with the rig crew were also areas of concern to the interveners, as was the BOP equipment to be used and the procedure for blowout practice drills.

A few interveners stated that drilling program information was incomplete. Previously drilled wells in the area indicated the possibility for lost circulation and over-pressured zones. The drilling program, in the interveners opinion, should include written procedures for handling such situations.

A major area of concern for all interveners was the emergency alert and evacuation plan proposed by the applicant. They generally suggested that the release rate calculated by Canterra was too low and that there was a need for a much larger evacuation zone than Canterra proposed. A number expressed concerns about the lack of evacuation routes out of the area, the means of communication with residents in the event of an evacuation, the need for special provisions for people with known health problems, and the care of livestock during an evacuation.

Most interveners contended that the effects on health and agriculture due to a blowout are not fully understood, as studies are not available on the effects of H_2S or sulphur dioxide (SO_2) on livestock and humans, especially long-term effects of low-level releases.

The appropriateness of testing the well and the feasibility of pipelining the well effluent, considering its composition, were questioned by the interveners. Concern was expressed that if a successful well was drilled more would follow, and if production could not be transported by pipeline, then a gas plant would be built in the area causing a further impact.

4 HEARING

The Board issued a preliminary notice of hearing in late November 1983 stating its intention to hold a public hearing of the application sometime in April 1984. Notice of a hearing to be held on 4 June 1984 was issued on 2 April 1984.

Several applications for a hearing delay were received from interested parties and a pre-hearing meeting on

---

[2] Interim Directive ID 81-3, Minimum Distance Requirements Separating New Sour Gas Facilities From Residential and Other Developments.

[3] The definition of this and other oil-field terms used in the report is given in Appendix 1, a Glossary of Terms.

TABLE 1 THOSE WHO APPEARED AT THE HEARING

Principals and Representatives (Abbreviations Used in Report)	Witnesses
Canterra Energy Ltd. (Canterra)	J. E. Martin, P.Eng.
F. M. Saville, Q.C.	W. H. Sawotin, P.Eng.
R. A. Neufeld	R. L. Thomas
C. P. MacDonald	R. Reid
	D. R. Lewis, P.Eng.
	J. K. Farries, P.Eng.[1]
	D. A. McCoy
	Dr. R. A. Crowther[1]
	M. B. Schroeder[1]
	Dr. D. M. Leahey[1]
	Dr. J. B. Hyne (A.S.R.C.)[1]
	D. P. Huffman
	D. A. McIntyre[1]
	J. Kingsbury, P.Eng.
	G. Brar, P.Eng.[1]
Bergen Ratepayers Association (Bergen Group)	S. Burton
S. R. Miller	M. Goodwin
	J. Grimstead
	C. Grimstead
	V. Milo, P.Eng.[2]
	J. R. Eickmaier, P.Eng.[2]
	N. E. Draper, P.Eng.[2]
	A. S. Murray, P.Eng.[2]
Inter-Varsity Christian Fellowship (Pioneer Lodge)	J. S. Fisher
J. S. Fisher	
Community of Fallen Timber (Fallen Timber Group)	B. L. Goodall, P.Eng.
B. L. Goodall, P.Eng.	
R. Bailey	
Town of Sundre	H. Doering
Mayor C. Vanderzwan	C. Currie
Mountain View Land Holders Group	
A. L. Dickson	
W. J. Waters	

[1] Consultants appearing on behalf of Canterra.

[2] Consultants appearing on behalf of the Bergen Group.

TABLE 1 (continued)

Principals and Representatives (Abbreviations Used in Report)	Witnesses
City of Red Deer Mayor R. J. McGhee C. Currie	C. Currie
Amoco Canada Petroleum Co. Ltd. M. L. Pillman	
S. Burton[3]	
G. E. Cloakey[3]	G. E. Cloakey
B. Goodwin[3] M. Goodwin[3]	M. Goodwin
J. Grimstead[3] C. Grimstead[3]	J. Grimstead C. Grimstead
I. Halvorson[3]	I. Halvorson
M. Halvorson[3]	M. Halvorson
T. Worobetz M. Worobetz[3]	M. Worobetz
The Bauman Family[3]	Dr. J. A. Bauman
J. Haug[3]	
J. Orr[3]	
Dr. R. Huisman	
Mr. A. Newell	
Energy Resources Conservation Board staff M. Bruni G. Dunn, P.Eng. D. Price, P.Eng. W. Thorne, P.Eng. C. Milbury, P.Eng.	

[3] Members of Bergen Ratepayers Association but also appeared on their own behalf.

25 May 1984 considered these requests. The Board deferred the hearing until 1 August 1984 to provide additional time for the interveners to prepare their submissions.

The public hearing of the application commenced on 1 August 1984 at Sundre, Alberta, before G. J. DeSorcy, P.Eng., C. J. Goodman, P.Eng., and L. A. Bellows, P.Eng., and continued through the days of 2, 3, 7, 8, 9, 10, and 11 August.

5 PRELIMINARY MATTERS

At the outset of the hearing, the Board dealt with several matters put forward by Dr. Bauman. He submitted that, for a number of reasons, the Board should dismiss the application or, failing that, postpone the hearing until any regulation changes resulting from the Lodgepole inquiry had been finalized.

Dr. Bauman argued that the notice of hearing referred to natural gas whereas the application contained a geological prognosis indicating that the H_2S component of the well effluent could be as high as 90 per cent. In the opinion of Dr. Bauman, the application was more representative of a liquid or gaseous sulphur extraction, and by his interpretations of the Act, this did not represent an energy resource and was therefore not within the jurisdiction of the ERCB.

In addition, Dr. Bauman argued that the application was incomplete because it failed to meet all of the requirements of the Draft Interim Directive attached to the Lodgepole Phase 2 report, in particular, section B, subsections 4, 5, and 6 of Attachment 1 to that document, referring to specific information to be submitted about the emergency planning zone.

Dr. Bauman contended that an apparent contact between the applicant and the Board staff during preparation of the application constituted a conflict of interest on the part of the Board. His view was that the Board had participated in the making and review of the application and therefore was not in a suitable position to decide it.

Mr. Cloakey expressed concern that the application made by Canterra lacked a site-specific emergency response plan and thus was incomplete. However, he preferred to deal with this during the hearing as opposed to having the hearing postponed to a later date.

In response, counsel for Canterra suggested that the Board dismiss the request of Dr. Bauman and continue with the hearing. The applicant argued that the definitions of "gas" and "raw gas" as outlined in the Act gave the Board jurisdiction to decide whether the type of well proposed should be drilled.

Canterra pointed out that the Draft Interim Directive referred to by Dr. Bauman was made public a few days after its submission was filed with the Board. It was Canterra's position that it was up to the Board staff to decide if the application was ready to go to a hearing.

The applicant submitted that contact between Board staff and the public, which includes Canterra, is a necessary process to fully understand what is required by the Board especially with respect to emergency planning.

After adjourning for about an hour to consider the arguments presented, the Board denied the requests of Dr. Bauman and the hearing proceeded. The Board stated that, in view of the definitions of "gas" and "raw gas" in the Act, it believed it had the jurisdiction to hear and decide on the Canterra application.

In regard to the Draft Interim Directive, the Board ruled that it had sufficient information before it to proceed with the hearing and that the purpose of the hearing was, at least in part, to test whether the information was complete and accurate. The Board stated that the applicant must satisfy it with respect to all statutory regulations and requirements before a well licence could be granted. It also confirmed that the Draft Interim Directive was in force and that Canterra must satisfy the Board on all aspects of that directive.

The Board also stated that it is appropriate for the staff to review applications, and as required, have contact with applicants, interveners, and other members of the public. Without this opportunity for communication, the entire process would be stifled or very inefficient due to misunderstanding of the meaning of directives, requirements for information in applications, hearing procedures, and other matters. The Board said that the process does not imply commitment regarding the approval of an application.

6 BASIS FOR MAKING THE DECISION

The applied-for well is clearly a critical well as defined in the Draft Interim Directive. Indeed, because the proposed well would be located in a fairly heavily populated rural area and the intended production would contain approximately 90 per cent H_2S, the Board believes a detailed assessment of the application is necessary before a licence could be contemplated.

The Board will first assess

- the purpose of the well and the necessity that it be located as proposed by Canterra.

There was much discussion at the hearing respecting the flow rate that could be expected from the proposed well and the resulting H_2S release rate should an accident oc-

cur. The Board believes this "maximum potential H_2S release rate" to be of underlying importance to public safety and all of the issues it would consider in assessing the application. For this reason it will next look at

- the maximum potential H_2S release rate for the proposed well.

Keeping in mind the estimated maximum release rate, the Board will then review the evidence and consider

- the precautions to be taken during the drilling of the well and the chances of a blowout occurring, and
- the actions to be taken in case of a blowout and impacts that could result.

Even though the application is for a well licence, the Board will next review

- the testing and production phases if a successful well is drilled andthe likelihood of further developments in the area.

The assessment of this final issue will be less detailed because subsequent applications would be required before such activities could proceed. This approach is consistent with the manner in which evidence was presented at the hearing.

Having reviewed the above listed issues, the Board will then consider all of them, giving appropriate weights to their relative importance, in making the decision as to whether a well licence will be issued and, if so, the conditions that should be attached to it.

7 PURPOSE OF THE WELL AND THE NECESSITY THAT IT BE LOCATED AS PROPOSED BY CANTERRA

7.1 Views of Canterra

The purpose and necessity of the proposed well were discussed at some length and in several contexts during the hearing. The well would be exploratory in nature with the company's main objective being to prove the presence of and evaluate the sour gas resources of the Leduc Member in the area. Other prospective zones would be tested for potential hydrocarbon recovery.

Canterra emphasized that it is in the business of exploring for and developing hydrocarbon and mineral resources. It contended that this well is a necessary part of that function. Canterra holds the mineral rights, and wishes to evaluate its holdings, and hopefully delineate its reserves by drilling the applied-for well. In addition, Canterra stated that it was necessary to drill the well to meet farm-in commitments.

Canterra also stated that the well would provide a high concentration sour gas source where it could test production methods. It proposed using catalyzed dimethyl disulphide as a solvent to reduce or prevent sulphur plugging in the well. Although it had not yet tested the solvent in any production conditions, it believed that the solvent would be substantially more efficient than anything used to date. Dr. Hyne stated that the solvent capability could be well over 200 weight per cent as compared with 30 weight per cent for carbon disulphide (which is currently in use).

It was Dr. Hyne's evidence that the use of catalyzed dimethyl disulphide puts the industry in a position to proceed with plans to produce high H_2S wells such as the one applied for. He said that testing of production methods at wells outside the Bentz Complex (Complex) may not be applicable to the proposed well. Mr. Martin, when asked about conducting tests at a well in 12-21-33-6 W5M (the Bearberry well), dismissed the possibility on the grounds that it was not owned by Canterra. He later stated that, even if Canterra owned the Bearberry well, it would still be the company's preference to go directly to the proposed location to establish reserves.

Canterra also addressed the issue of necessity from the point of view of product markets, and stated its prime interest in this area was sulphur. The company stated that it is one of the largest sulphur producers in Canada and "Through Cansulex. . . . Canterra accounts for 8 to 10 per cent of the world sulphur trade". Approximately 90 per cent of its production is exported and the majority used for the production of fertilizer. Mr. Martin and Dr. Hyne both commented on the long-term outlook for sulphur marketing and indicated that the demand would meet or exceed supply on a worldwide basis within this decade.

Canterra stated that its ability to satisfy demand would be reduced beyond 1988 as more accessible inventories are depleted. In order to maintain its sales at current levels, new reserves, such as those in the Complex, will be needed.

Mr. Martin also commented on the overall economic benefit to all Albertans, and that the sulphur industry contributes approximately $250 per person per year to our standard of living.

Canterra was asked a number of questions on the possibility of producing this reserve without drilling at the proposed location. In response, it stated that there was little alternative based on its interpretations of the geological information. Canterra said that a directional well may be a possibility, but this would not significantly affect the surface location and might adversely affect drilling safety by complicating the drilling program.

7.2 Views of Interveners

A number of local interveners questioned the purpose and necessity of the proposed well. In particular, some alluded to the inexperience of industry not only in drilling but also producing wells containing 90 per cent H_2S. Mr. Cloakey, in his closing remarks, indicated that a number of technical matters "were not fully understood" nor "proven". Although these interveners related this matter more to safety than purpose or necessity, citing Canterra's lack of experience in the production or testing of such a well, there appeared to be a view that the need for the well was also questionable.

Some interveners suggested the possibility of testing the Bearberry well instead of drilling and testing at the proposed location. While the interveners seemed to argue that position mainly in a reservoir evaluation context, it was also implied that the production testing using the new solvent should be done elsewhere.

Several interveners questioned the need for sulphur production. While they did not present evidence to contest Canterra's prediction of world sulphur requirements, there was some suggestion that current sulphur inventories and reserves were adequate to meet foreseeable requirements.

Mrs. Grimstead expressed a view that the rights of industry were being given a high priority compared to environmental costs, which would be borne by the public. She made these comments on behalf of the Bergen Group as well as herself. The interveners generally acknowledged the legal rights of industry to explore for and win its minerals, however, the theme of their concerns was that this right could impose adverse effects on at least particular sectors of the public.

Although there were some questions to Canterra regarding the possibility of drilling this well from another location, there was no evidence to suggest that this particular reserve could be evaluated and tested from such a location.

7.3 Views of Board

The Board has carefully considered the evidence respecting the purpose and necessity of the proposed 12-12 well. It notes that Canterra has a lease and a right to explore it, subject to satisfying regulatory and other Alberta laws. The additional reserves of natural gas and particularly sulphur, and the technology which Canterra hopes to prove, would represent significant benefits to Alberta and Canada. Although the Board recognizes these factors as important, it agrees with many of the interveners that such factors must not override producing the resource in a manner which is acceptable in terms of impact on the public, particularly public safety. As a consequence, even though it believes there is an adequate need for the proposed well, the Board must satisfy itself on the issues of public safety and other impacts before it would grant the requested well licence.

The Board considered requiring the applicant to evaluate its new production technology and solvent at some other location, more remote from farms and centres of population. Although it is of the view that conducting the test at such a location would be desirable, it notes Canterra's evidence that the technology would have to be tested in the specific reservoir to be certain of its success and to design proper production facilities. The Board also recognizes that testing the technology at a remote location would not address a primary purpose of the proposed well, that is, to explore and prove-up possible reserves. For these reasons, the Board is not prepared to deny the application to drill the proposed 12-12 well solely because the technology could be tested elsewhere. On the other hand, the Board is aware that Canterra has more remote leases elsewhere in the province which involve high H_2S gas. It understands that Canterra plans to test its technology at a well in such a setting in the near future. If the testing is carried out and is unsuccessful, thus suggesting that the technology has little chance of working, one of the major reasons for drilling the proposed 12-12 well would be significantly changed. With this in mind, if the Board finds that the 12-12 well can be safely drilled and is prepared to issue a licence, it would condition the licence so that commencement of drilling would not be allowed if tests in the province have raised significant doubts as to whether the proposed technology is likely to be successful.

With respect to the specific proposed location, the Board heard no evidence suggesting that there might be a better local surface location which would accomplish the purposes of the 12-12 well.

8 MAXIMUM POTENTIAL H_2S RELEASE RATE

8.1 Views of Canterra

Canterra estimated an H_2S release rate of 3.85 m^3/s which reflects a flow rate of 370 thousand cubic metres per day (10^3 m^3/d) (13.1 MMCFD) and a 90 per cent H_2S content.

Canterra used two methods in attempting to estimate the H_2S release rate from the proposed well. The first was to determine the most representative pool in the immediate area, and the second was to look at other Leduc pools in the general area and compare them to the most representative pool. It also considered sulphur deposition and its impact on expected flow rates.

Canterra stated that the proposed well is postulated to be part of the Complex, so wells in the Complex most closely approximate what is to be expected. The Complex well having the most available information is the Bearberry well drilled by Shell. Canterra therefore based its estimate on the 1969 absolute open flow potential (AOFP) test at that well.

Canterra emphasized that the quality of the test was somewhat questionable as essential pieces of data, such as field notes, surface pressure measurements, and volume of injection fluid, had not been recorded. However, from the test data, Canterra calculated a sandface AOFP of 760 x 10^3 m^3/d (27 MMCFD) and, assuming single-phase gas flow up the tubing, a wellhead AOFP of 563 x 10^3 m^3/d (20 MMCFD). This flow rate would result in a higher H_2S release rate than the submitted 3.85 m^3/s but Canterra contended that the assumption of single-phase gas flow made the estimate highly optimistic. It suggested that the actual wellhead AOFP would probably not exceed 155 x 10^3 m^3/d (5.5 MMCFD) if information on the amount of condensate being circulated, the amount of sulphur deposition, and a two-phase flow diagram had been available from the Bearberry test.

Canterra performed statistical analysis of wells in other Leduc fields in the immediate area. The study included the Bearberry well and wells from Ricinus and Harmattan-Elkton pools. A log-probability plot of 10 AOFPs indicated a 50 per cent probability of a flow rate of at least 370 x 10^3 m^3/d (13.2 MMCFD) which corresponds to an H_2S release rate of 3.85 m^3/s. Canterra stated that this supported its first estimate of a release rate using data from the Complex.

Canterra stated that West Ricinus wells were not included as they were not representative of the Bentz structure. However, when questioned about the geological differences between the pools, Canterra agreed that the differences between West Ricinus and the Complex were the same as between Ricinus and the Complex. However, it emphasized that there were differences in the reservoir fluids which would affect the capability of the wells.

Canterra also presented evidence respecting sulphur deposition to support its estimated H_2S release rate. It contended that the reservoir fluid in the Bearberry well is a supercritical gas because the compressibility and viscosity of the fluid were those of gas and not a liquid as was suggested by the Bergen Group. It also said that there is adequate evidence of sulphur plugging in the Bearberry well. The reservoir characteristics, porosity, and permeability are indicative of a much more prolific reservoir than the production tests showed. Sulphur deposition had significantly reduced the pore structure in the reservoir around the bottom hole and the test would not have been successful if solvent had not been circulated into the well. Canterra noted that the very rapid pressure build-up following the production test was further evidence of sulphur plugging.

Canterra submitted that, when a sour gas fluid is saturated or nearly saturated with sulphur, the amount of sulphur deposition depends on the pressure drop along the flow path from the reservoir to the wellhead. A larger pressure drop, such as would occur under open flow or uncontrolled conditions, would immediately decrease the sulphur carrying ability of the fluid. The minimum impact would be the precipitation of sulphur in the pore structure around the bottom of the hole and for some distance back into the reservoir. It stated that both field and laboratory experimental data on fluids containing a much lower percentage of H_2S than the 90 per cent expected in the subject well supported the concept that the faster the fluids flow the greater the sulphur deposition. Canterra concluded, therefore, that under blowout conditions the extent of sulphur deposition would be far greater than under normal operating conditions, and the flow rate would thus be rapidly reduced.

Canterra acknowledged that, under very high flow rates, it would be possible for the fluid to carry some of the precipitated sulphur from the reservoir up the tubing to the wellhead. Canterra said, however, that the scouring effect in the formation would probably not remove all the sulphur.

8.2 Views of Interveners

The Bergen Group presented several different approaches for estimating the H_2S release rate, four of which used data from the Bearberry well. The first estimate used the semi-steady state flow equation and conservative reservoir and fluid parameters to calculate a flow of 6070 x 10^3 m^3/d (215 MMCFD) assuming no "skin damage" and a permeability of 15 millidarcies (md). The Bergen Group acknowledged that initially there could be skin damage but stated that it would clean up after a brief flow period.

The second approach dealt with the specific productivity index. The Bergen Group submitted that the productivity index increased from 78 to 323 cubic feet per day per pounds per square inch (psi) drawdown during the Bearberry well test, which indicated the well was cleaning up. It assumed a drawdown of 2500 pounds per square inch absolute (psia) and used the productivity index of 323 cubic feet per day per psi to calculate a flow rate of 6600 x 10^3 m^3/d (234 MMCFD).

The Bergen Group also interpreted the Bearberry test and calculated an AOFP of 9160 x 10^3 m^3/d (325 MMCFD) using an "n" value of 1.0 which it stated should be used

because the reservoir fluid was a liquid and would act as a liquid at reservoir conditions.

The Bergen Group submitted that the product of viscosity times the volume factor from the pressure volume temperature (PVT) data on the Bearberry well was relatively constant from the initial reservoir pressure of 5345 psia (36 855 kilopascals (kPa)) down to the bubble point. It then concluded that the fluid in the well would act as a liquid for pressures above the bubble point and that the rate-drawdown relationship would be linear, resulting in an even higher AOFP of 12 680 x 10^3 m^3/d (450 MMCFD).

From the four methods outlined above, if one assumes a 75 per cent value for the wellhead-sandface flow relationship and a 90 per cent H_2S content, the H_2S release rates would range from 47 to 99 m^3/s. The Bergen Group therefore concluded that the Bearberry well is completed in an extremely prolific reservoir.

The Bergen Group also performed a statistical analysis, consisting of individual and combined flow rate probability plots for the Harmattan-Elkton, West Ricinus, and Strachan Leduc pools. It noted that the combined probability plot resulted in a straight line, which is indicative of the data points being from the same population. The Bergen Group maintained that in this statistical analysis, a 10 per cent level of probability should be used as a conservative approach to protect the public. The Bergen analysis indicated a 10 per cent chance of the H_2S release rate being greater than or equal to 47.9, 98.9, and 100.9 m^3/s for the Harmattan-Elkton, West Ricinus, and Strachan pools, respectively. The combined plot results in an estimated release rate of 93.6 m^3/s.

The Bergen Group pointed to Canterra's own statement that "Canterra does not know the H_2S content in this well until they get a sample and that where sulphur will precipitate depends on how close the sulphur content approaches sulphur saturation and flowing temperature and pressure." It thus concluded that the influence of sulphur deposition on the flow rate would be unpredictable and should not be relied upon to significantly affect the flow rate from the proposed well.

8.3 Views of Board

The Board believes that in some instances a statistical analysis of AOFPs in other fields in the area of a proposed well would be a reasonable approach in determining the expected H_2S release rate of the well. However, in this case, the Board is of the opinion that because the proposed well is expected to be in the same complex as the Bearberry well, that well would likely be the most representative and a statistical approach would, in all likelihood, diverge from, rather than converge to, the best release rate estimate.

While the Bearberry well is of the most significance in estimating the H_2S release rate, the Board acknowledges that the actual test is of questionable quality. Its interpretation of the test indicates that the sandface AOFP could be as low as 760 x 10^3 m^3/d (27 MMCFD) as was calculated by Canterra. It does not believe the upper limit would be as high as suggested by some of the calculations submitted by the Bergen Group, but accepts that it could be as much as 1970 m^3/d (70 MMCFD). The latter estimate ignores possible effects of multiphase flow upon the calculated deliverability.

The Board believes that for wells such as that proposed, in the event of an uncontrolled flow, sulphur deposition would probably reduce the flow of fluid from the wellbore. The extent of this reduction, and whether or not the well would plug off completely is, at this point in time, not known. The Board notes that during normal producing operations, sulphur deposition causes restriction of flow in many sour gas wells throughout the province. However, to extrapolate this reduction of flow under producing conditions to a complete or even partial plugging off of flow during a blowout would not, in the Board's judgement, be prudent when estimating a release rate for purposes of protecting the public.

Using the conservative approach of neglecting the possible effects of sulphur deposition and multiphase flow, and assuming the wellhead deliverability to be 75 per cent of the sandface AOFP and a 90 per cent H_2S content, results in an H_2S release rate ranging from 6 to 15 m^3/s.

The Board does not necessarily expect that if the proposed well was drilled and a blowout occurred, the H_2S release rate would be as high as 6 to 15 m^3/s but believes it appropriate to consider that range for emergency planning purposes. Should the well be licensed and an ignition requirement be included as a condition of the licence, the latter would reduce the significance of estimates of the H_2S release rate.

9 PRECAUTIONS TO BE TAKEN DURING DRILLING AND THE CHANCES OF A BLOWOUT — NON-CRITICAL WELL SECTION

This section of the report deals with drilling the proposed well to a depth of approximately 3775 metres (m), some 110 m above the Leduc Formation in which sour gas may be expected.

9.1 Views of Canterra

Canterra's main objective was to evaluate the Leduc[4] Formation at 3887 m. It also identified a number of secondary objectives from the Cretaceous at approximately 1450 m through to the Beaverhill Lake at approximately 4140 m, the latter being below the primary objective of the Leduc Formation. The company would set 600 m of surface casing and then drill the "intermediate hole" to 3775 m, just above the Nisku and above the Leduc. This section of the hole would then be cased and cemented full length. The company acknowledged some possibility that the Rock Creek and Banff formations could have abnormally high pressures. It was also questioned about the Beaverhill Lake, but expected very low porosity and no abnormal pressure.

The company's general plan is to drill the intermediate hole using a diesel oil based invert emulsion mud system. The mud density would be increased to 1320 kilograms per cubic metre (kg/m^3) at a depth of 3025 m to ensure sufficient bottom-hole hydrostatic pressure is maintained through the Rock Creek (3172 m) and Banff (3322 m) formations. This would minimize the chances of any influx from these formations. Through the Cretaceous sequence (to 3025 m), the mud density would be maintained at a lower level as there was no evidence of abnormally pressured strata.

While Canterra accepted there had been some drilling difficulties with previous wells in the area, it generally took exception to the premise that this area presented special difficulties. It emphasized that the drilling program, as outlined, should effectively handle the predicted pressures as well as any other problems that may occur.

The company stated that lost circulation or underground blowouts, should either occur, would be handled by the use of high density mud, barite plugs, or by the use of cement. The applicant said that the chances of an underground blowout would be extremely low since all uphole formations would be cased and cemented prior to drilling through the Nisku and Leduc formations.

As indicated above, intermediate casing would be run to a depth of 3775 m and cemented full length with full strength cement from 3775 to 2200 m and filler cement above that. Canterra stated that offset well data indicated that the formation strengths were sufficient to withstand the full length cement job as proposed. The cement would not have an appreciably higher density than the mud proposed for the intermediate hole.

The company indicated that the intermediate casing was designed to meet current regulations and will be monitored for wear by intermittent pressure testing and caliper logs. If the intermediate casing is damaged during subsequent drilling operations, the company would repair the damage by the use of a casing patch or a tie-back casing string.

The applicant did not specifically state in its application or during the hearing how it would establish formation breakdown pressures in the intermediate hole, but did indicate that offset well data would be used to ensure dequate casing design and identify any overpressured zones.

9.2 Views of Interveners

The Bergen Group, through questioning, expressed concern for the possibility of encountering overpressured zones, as indicated by offset well data. It suggested that Canterra had not outlined a procedure that would be used to drill through the transition zones leading to and through the actual overpressured zone.

Mr. Murray expressed concerns about lost circulation and underground blowouts, but was not specific as to where the problems may arise. He also stated that Canterra should have a method outlined for testing the integrity of open formations to allow the drilling personnel to establish maximum allowable shut-in pressures. If this maximum shut-in pressure was not established, it is possible that if a high pressure kick from a lower zone entered the wellbore and the well was shut in, a weaker zone higher in the hole could be charged up to the higher pressure. This high pressure zone could cause a blowout in future drilling operations if such an underground blowout went undetected.

Mr. Murray also said that the procedures to be used in the placing and cementing of the casing string would be important in maintaining well control should a kick situation be encountered and suggested that the company should submit written procedures to outline pressure testing of the casing during drilling operations.

In addition, the Bergen Group expressed a number of other concerns which relate to the non-critical section of the well but, more importantly, to the critical section. These items are covered in the next section of this report.

9.3 Views of Board

The Board generally concurs with the outlined drilling procedures up to the point of setting intermediate casing. However, if it issues a licence, it would require the company in its detailed drilling plan to satisfy the Board with respect to:

---

[4] Appendix 3 is a typical cross-section of geological formations in the region.

- the establishment of formation breakdown pressures in the intermediate hole, and

- casing inspection methods and testing frequency.

The Board notes that the mud density would be increased to 1320 kg/m^3 for certain zones and believes this weight to be sufficient to safely drill the zones, but would review the matter further when the final drilling program is submitted.

Although the Bergen Group's expert witnesses expressed concern about overpressured zones, possible lost circulation, or an underground blowout in the intermediate hole, the Board notes that no critical sour zones are expected to be penetrated. It concludes that there is nothing particularly unique about the intermediate hole, and that neither the chances nor the consequences of a blowout from the intermediate hole would be serious. If the well is drilled, the Board believes the primary objective with respect to the non-critical section would be to ensure proper design, running, and cementing of the intermediate casing in order that the well may be controlled should problems occur after entering the critical zone.

10 PRECAUTIONS TO BE TAKEN DURING DRILLING AND THE CHANCES OF A BLOWOUT — CRITICAL SECTION

This section of the report deals with the drilling of the proposed well through the Nisku and Leduc formations after the intermediate casing had been set. Due to the potential high H_2S gas and the resulting seriousness of the situation if problems occur, the Board is focusing particular attention on this "critical section" of the proposed well.

It should be noted in this and subsequent sections of the report that although the interveners opposed approval of the application to drill the well, they presented evidence as to conditions which should be imposed if the well is drilled.

10.1 Geological Prognosis

10.1.1 Views of Canterra

Canterra stated that the pressure gradients of the Nisku and Leduc formations as indicated by the offset wells are lower than a water gradient, which would indicate that neither of the zones are overpressured. The applicant said that the Nisku Formation in the area is non-productive and stated that none of the offset wells had experienced any lost circulation problems.

Canterra contended that the submitted drilling program sufficiently covered all possible problem areas indicated by the geological prognosis based on offset wells.

10.1.2 Views of Interveners

In general, the interveners did not disagree with the geology as outlined by the applicant, although several items of evidence were submitted by the Bergen Group which suggested problems occurred during the drilling of several other wells in the area.

Concern was expressed by Mr. Murray that if the Nisku proved to be productive, it could be a lost circulation zone. He also said the possibility exists that the Leduc could be an abnormally high pressured zone.

10.1.3 Views of Board

A review of the daily drilling reports submitted by the Bergen Group reveals that, with the exception of two events connected with drill-stem tests at the 11-35-33-7 W5M well, all other problem events related to the non-critical zones of the proposed well, zones which will be cased-off when drilling in the critical Leduc and Nisku formations. These non-critical well section matters were dealt with in section 9 of the report. The two drill-stem test problems appeared to relate to sulphur plugging of the drill pipe and were not the result of unusual pressures or lost circulation in the Nisku or Leduc zones.

It is the Board's view that the Nisku and Leduc are likely underpressured zones as indicated by the offset well information. The semi-dispersed gel system proposed for the drilling of these sections should be adequate to ensure good well control. Procedures for controlling lost circulation will be reviewed in greater detail when the final program is submitted.

As a consequence of its review of the geological prognosis, the Board would not expect that serious problems would be encountered while drilling the Nisku and Leduc formations. Nevertheless, there is always uncertainty as to what will be found, and caution is always necessary.

10.2 Casing Design and Its Impact on the Critical Section

10.2.1 Views of Canterra

The critical section of the well would be drilled through the Nisku, Leduc, and Beaverhill Lake formations. The program calls for drilling through the Nisku and coring the Leduc Formation. If the Leduc proved successful, the well would be cased and then the Beaverhill Lake would be drilled. If the Leduc was not successful, drilling would continue to a projected total depth of 4287 m, below the Beaverhill Lake, and then casing would be set to total depth.

Canterra, in response to questioning by the interveners, indicated that intermediate casing wear was to be

monitored by running caliper logs and by pressure testing the casing while drilling the main hole. If either test indicated excessive casing wear, remedial action would be taken depending on the situation, and the applicant would obtain Board approval for such action. It was Canterra's view that the pressure rating of 61 megapascals (MPa) (burst rating) for the proposed casing was adequate. If higher than expected pressures were encountered, an additional casing string would be placed in the hole to withstand such pressures and isolate the outer casing.

The applicant stated that cathodic protection would be used to control external corrosion on the completed well. Additionally, annular spaces between tubulars would be filled with inhibited fluid to help prevent internal corrosion. Canterra also indicated that it had significant experience in the area of corrosion control and was confident that its corrosion program was adequate.

10.2.2 Views of Interveners

The Bergen Group expressed concern that the intermediate casing would be subjected to extensive wear as a result of drilling the main hole. Concern was also expressed that the pressure rating of this string may not be sufficiently high to withstand the pressures which might exist in one of the secondary objectives, such as the Beaverhill Lake.

Corrosion, in the view of the interveners, should be a major concern when considering the well design, not only the internal corrosion of the tubulars but also the external corrosion of the casing strings.

10.2.3 Views of Board

Generally, the Board is satisfied with the casing and cementing details, and considers it particularly important that if the Leduc proves productive, it be cased off before drilling deeper. The question of casing wear and the need to deal with it in the detailed drilling program has been dealt with under section 9.

The Board is satisfied with the corrosion control measures as outlined by the applicant. It is aware that the measures proposed by Canterra are proven methods used extensively in other sour gas operations.

10.3 Drilling Equipment

In response to questioning, Canterra identified the equipment it was proposing to use for the applied-for well. Although the company declined to fully describe specific equipment because a drilling contractor had not yet been selected, it was specific on most of its requirements. While there was considerable questioning about many items, the discussion can be divided into that dealing with five major categories of equipment:

- Blowout preventers and associated equipment
- Mud-conditioning equipment
- Drill pipe
- Kick-detection equipment
- H_2S trim equipment

10.3.1 Blowout Preventers and Associated Equipment

10.3.1.1 Views of Canterra

Canterra stated that it would be using a Class V[5] pressure rated BOP stack and manifold system with manifold arrangement as specified for Class VI. The stack would be modified by adding a spacer spool and a second set of pipe rams. This was done to eliminate the necessity of relying on the annular preventer to circulate a shut-in well. The stack and manifold specified would have a pressure rating of 35 000 kPa and the company indicated that it would be pressure tested in accordance with applicable requirements of the ERCB regulations. Canterra said it had decided to include a set of shear rams on the stack, and it would be located immediately below the blind ram on the Class VI configuration.

Canterra stated that the pressure testing and inspections of the BOP equipment would meet or exceed all Board regulations. Pressure tests would be performed on this equipment at various times including before drilling out of surface casing, prior to weighting up the mud system at a depth of 3025 m, before drilling out of intermediate casing and before entering the Leduc Formation. Each of these tests would involve a low pressure test and a high pressure test. Surface casing would be pressure tested to 12 600 kPa and the intermediate casing would be tested to a pressure of 23 700 kPa.

In response to the Bergen Group's questions respecting selection of a Class V BOP stack with a pressure rating of 35 000 kPa, Canterra stated that the pressure rating was suitable notwithstanding bottom-hole pressures in the Bearberry well may exceed this rating.

Canterra indicated that the choke manifold would be located away from the rig substructure approximately 20 to 25 m, and that there would be dual flare lines, one running to each side of the drilling site. Canterra stated that it had no preference in the type of pressure sensors used (piston or diaphragm), however, it agreed that thorough maintenance of these items was important.

---

[5] Classes as described in Schedule 8, Oil and Gas Conservation Regulations.

Canterra said that there would be two BOP control panels, one near the driller's station and one at a "remote" location (at the accumulator unit). It expected that the controls would be electric but this would not be known until the rig was selected.

10.3.1.2 Views of Interveners

As well as addressing a number of questions to Canterra about the BOP equipment, the Bergen Group raised doubts through direct evidence respecting Canterra's plans. Mr. Murray questioned Canterra's ability to strip into the hole using the BOP stack as proposed. Mr. Sawotin, Canterra's drilling specialist, said that this operation would be done by alternately opening and closing the annular preventer and one of the pipe rams, thus allowing the tool joints to pass through the BOP stack while keeping the well closed in. Mr. Murray maintained that the annular preventer should be used only as a last resort and not unless "you really have to".

Mr. Murray also questioned Canterra's use of the cross below the lower pipe ram to bleed off any well pressure because if it were to be washed out (fail) there would be nothing left below the lower pipe rams to control the well.

Although the Bergen Group did not present an opinion about the pressure rating of the BOP stack and manifold system, it implied through questioning that the 35 000 kPa rating would be insufficient for this well, citing the somewhat higher bottom-hole pressure at the Bearberry well in the Leduc Formation.

10.3.1.3 Views of Board

The Board has considered the concerns expressed in connection with BOP equipment specified for use by Canterra, and although they are matters of interest, most of them are covered by appropriate design standards and regulations. The Board believes it appropriate, however, to comment on the major items addressed at the hearing.

The Board is satisfied that the equipment as proposed would have the capability to control the applied-for well if the equipment is operated and maintained in a workmanlike fashion. The shut-in pressure of approximately 18 700 kPa at the Bearberry well is believed to be representative of what can be expected at the proposed well and the Board is satisfied with the pressure rating of the proposed BOP equipment. The addition of a shear ram to the BOP stack would provide added safety features.

The Board finds the BOP stack arrangement and control system as proposed by Canterra to be acceptable, as well as its procedures to strip into the hole if necessary. The Board also concurs with Canterra's decision to use dual flare pits.

The pressure testing and inspections of the BOP equipment, and the blowout prevention drills, as outlined by the applicant are generally satisfactory. Such procedures are extremely important, however, and if a well licence is issued, they must be detailed in the final drilling program and further reviewed at that time.

10.3.2 Mud-Conditioning Equipment

10.3.2.1 Views of Canterra

Canterra would use the typical mud system for a well of the depth proposed, but additionally would use two so-called "poorboy" atmospheric pressure mud gas separators as the primary means of removing gas from the mud. It would also use a vacuum degasser to remove smaller quantities of entrained gas from the fluid. The second poorboy degasser would be used as a back-up to the first and would be remote from the rig.

The applicant planned to use a jet mixer for weighting up mud and stated that this would provide the best solution to quick weight-up requirements. It was Canterra's opinion that a standby mud system was not necessary as the drilling fluids would be maintained with sufficient yield point to ensure that the fluids could be weighted up as required.

10.3.2.2 Views of Interveners

None of the interveners presented detailed evidence respecting this matter, although Mr. Murray did question Canterra's ability to weight up severely gas-cut mud. He also suggested that a standby mud system would be more appropriate than the jet mixer proposed by the applicant. He said it was necessary to have the mud previously mixed to ensure that the fluid had a sufficient yield point to suspend the barite being added.

10.3.2.3 Views of Board

The Board has reviewed the statements of Canterra together with the information filed and believes if a licence is issued, the company should address more fully the methods of mud conditioning in its detailed drilling program. The plan should include a schematic of the mud circulating and conditioning systems, including the location and operation of isolating valves and redundant equipment. It should also provide for a volume of mud at surface, within the active mud system, in the order of 150 per cent of the hole volume at the time of drilling out the intermediate casing and throughout operations in the critical zone. It also should fully address the mechanics of monitoring the mud system, dealing with gas-cut mud, avoiding "clobbered" mud, and of weighting up mud.

The Board believes there is merit in having available an extra supply of premixed mud as well as the proposed high speed mixing equipment for the critical section of the well. It recognizes Canterra's position that reliance on a jet mixer would provide greater flexibility, but nevertheless is concerned at the time it may take to mix additional volumes if needed. For these reasons, the Board believes it would be appropriate to have the previously indicated excess volumes of mud, some 150 per cent of hole volume as compared to something less than 100 per cent as is more typically the case. The Board would also require that the jet mixer along with adequate accessible ingredients be available on site.

10.3.3 Drill Pipe

10.3.3.1 Views of Canterra

Canterra stated that it planned to use Grade E drill pipe for this particular well. For an overpull of 30 000 decanewtons, and omitting buoyancy effects, Canterra estimated a safety factor of 20 per cent on tensile strength. In addition to meeting the API[6] and NACE[7] standards respecting drill pipe, Canterra said that it would be carrying out ultrasonic inspection on the drill pipe and magnetic particle inspection of the tool joints. Conformance to NACE standards would be evaluated on the basis of hardness testing.

Canterra said it has metallurgical experts within the company who would supervise third-party inspection of the drill pipe prior to the well being drilled.

10.3.3.2 Views of Interveners

Although none of the interveners suggested that the use of Grade E drill pipe was unsatisfactory for the application proposed, Mr. Murray, on behalf of the Bergen Group, commented on the use of outside consultants and inspectors, particularly with regard to drill pipe inspection. He stated that inspection of the drill string should occur before spudding the well, before drilling out the intermediate casing, and after any sour gas invasion into the wellbore. The inspections should be done by a well-qualified inspection company and supervised by the applicant. Mr. Murray emphasized that a third party should not be totally relied upon to give accurate unbiased opinions and suggested that the company must have the expertise in house.

10.3.3.3 Views of Board

The Board concludes that with proper procedures the Grade E drill pipe proposed would be adequate for the well. The Board acknowledges the statements made by Mr. Murray regarding inconsistent inspection results, and agrees that the applicant must accept the responsibility for the pipe being properly inspected, even though the inspection would be by third-party experts.

Additionally, the Board believes that the drill pipe must be fully inspected prior to, and protected and maintained during, the drilling operation. If it issues a licence, the Board would require Canterra to specifically detail in its drilling program all matters in connection with the drill-string inspection, protection, and maintenance. The company should consider and show in detail its proposed methods of corrosion inhibition, H_2S scavenging, and maintenance inspections after the string has been contacted by H_2S.

10.3.4 Kick-Detection Equipment

10.3.4.1 Views of Canterra

Canterra stated that it would be using an electrically operated pit totalizer with probes in each active tank. In addition, the company would use a flow totalizer and a trip tank. The company also indicated that there would be continuous display readouts of tank levels and fluid flow information near the driller's station. Mr. Farries indicated that although the alarms may be set to detect very small pit gains, it would be realistically difficult to detect a pit gain of less than one cubic metre.

10.3.4.2 Views of Interveners

Mr. Murray, representing the Bergen Group, expressed concerns with the proposed kick-detection equipment. He indicated a concern with the ability of pit level indicators to give accurate results if the drilling fluids become "clobbered".

10.3.4.3 Views of Board

The Board generally agrees with the use of the kick-detection equipment proposed by Canterra but believes that a complete description of the equipment and its capabilities is necessary to fully evaluate its suitability. If the requested licence is issued, the detailed drilling plan should indicate the location, function, and application of each piece of equipment in the system. It should also address the matter of kick detection under adverse mud conditions (eg, gas-cut mud or "clobbered" mud).

The Board believes that the proper use of kick-detection equipment, and indeed essentially all drilling equipment,

---

[6] American Petroleum Institute.

[7] National Association of Corrosion Engineers.

is equally important as the equipment itself in avoiding a blowout. For this reason, the detailed drilling program would also have to satisfy the Board that the crew will be properly trained respecting the use of kick-detection equipment and that particular care will be taken in this regard.

10.3.5 H_2S Trim Equipment

10.3.5.1 Views of Canterra

Canterra stated that it would inspect all equipment at the time of spudding the well to ensure that it meets NACE MR 0175 and API standards. In general, it stated that all equipment which could be contacted by drilling fluids would be sour service rated. The company further stated that it would employ third-party inspection organizations to inspect drill pipe and it would replace components that could not be confirmed to be suitable for sour service. Mr. Sawotin, Canterra's drilling expert, stated that the high concentration of H_2S did not pose any special problem. Mr. McIntyre, Canterra's corrosion specialist, indicated that sulphide stress cracking was a function of the H_2S partial pressure and not a function of H_2S concentration alone.

Canterra said that although it would rely upon a third-party service company to perform some of the required testing, the company would also have a representative on site to perform inspections and ensure that all items were in compliance with sour service standards. The company also produced a copy of its standard drilling rig inspection check-list, and generally took the position that the high H_2S concentration did not pose problems that were not present at lower H_2S concentrations, particularly in relation to corrosion matters.

10.3.5.2 Views of Interveners

The Bergen Group, through Mr. Murray, expressed considerable concern about Canterra's ability to ensure that materials would meet sour service specifications and that all necessary maintenance would be looked after. He commented on the difficulty in finding a drilling rig that would meet all of the necessary criteria, and recommended that Canterra should have an expert in drilling equipment who would ensure that all equipment deficiencies were corrected and that all equipment would conform to the proper specifications.

Mr. Milo, on behalf of the Bergen Group, recommended a number of steps for a good corrosion-control program and also for a materials-selection program. He said that from what he had heard at the hearing, Canterra had a reasonable understanding of the potential problems and principles involved but had not demonstrated that it "recognized the importance of the follow-up procedures and the need to assign responsibility for implementing them". Mr. Milo stated these were very important and that the ability to maintain workable equipment under adverse conditions depended on having a program in place to recognize the problems and prescribe methods of dealing with them.

He suggested that acceptance of the common industry practice of labelling and spot checking as evidence of sour trim suitability was "grossly inadequate" for this application, and he further commented that it did not appear to him "that the knowledge or ability to furnish sour gas resistant material would be a major factor in the selection of the drilling contractor". Mr. Milo went on to say that the expertise appears to exist within the Canterra organization, as evidenced by its stringent sour gas line pipe specification, but that it needs to be implemented into a materials-selection criteria, a corrosion-control program for drilling, and in the rig-selection process.

10.3.5.3 Views of Board

The Board has reviewed the "Rig Safety Check List" as provided by the applicant, together with its statements and those of interveners. The Board is in general agreement with the interveners on these matters and believes that, to evaluate a rig and equipment for the intended service, Canterra will have to develop a full set of acceptance criteria and a detailed surveillance program. In the Board's view, the Canterra "Rig Safety Check List" is acceptable for general field inspections, but is not detailed enough for rig and equipment selection and material suitability for very critical wells like the one proposed.

If it approves the application, the Board would require as part of the final drilling program that Canterra outline its equipment selection and maintenance program in sufficient detail to satisfy the Board that these matters are not likely to create problems.

10.4 Safety Equipment

10.4.1 Views of Canterra

Canterra indicated that all normal oil-field safety equipment and procedures would be used. It stated that it was confident that the respiratory equipment now used by the company would be adequate in the event that high concentrations of H_2S were present in the atmosphere. However, it agreed that in the event of a release, H_2S concentrations could be higher around this well site than for the average one, but it had not done any special testing of the equipment. The company pointed out that it had considerable experience in the use of respiratory equipment at its various plant sites, including some potentially high concentration areas, and was convinced that the equipment was suitable for use at this location.

10.4.2 Views of Interveners

The Bergen Group, through Mr. Murray, expressed concern as to whether or not the proposed respiratory equipment was suitable for both SO_2 and H_2S, and whether all components were compatible with the environments to which they could be exposed.

10.4.3 Views of Board

The legislated responsibility for worker safety rests with the Occupational Health and Safety Division (OH&S) of Workers' Health, Safety and Compensation. The Board, however, is concerned that safety equipment and procedures must be adequate because failures in this regard could turn a minor drilling problem into a major one or perhaps a blowout. For this reason, the Board would, if it issues the requested well licence, contact OH&S for advice and direction as to whether Canterra's proposals respecting safety matters are adequate. To facilitate the review by OH&S, the Board asks that Canterra include in its final drilling program information respecting safety equipment and procedures.

10.5 Supervisory and Other Personnel

10.5.1 Views of Canterra

The applicant said that the staff assigned to the site would include one drilling engineer, one geologist, one mud engineer, two drilling supervisors and two mud loggers. In Canterra's view, assigning the above staff during drilling from 3100 m to total depth would be adequate. During this drilling period, two of the three senior drilling personnel (two drilling supervisors and the toolpush) would be on location, either on site or at the camp, 24 hours per day. While drilling the main hole beneath the intermediate casing at 3775 m, four safety personnel would be assigned to the operation. Well-site operations would be handled by one of the safety personnel and contingency planning would be handled by the other. The remaining two would be acting as a back-up crew to ensure no one works more than 12 hours without replacement.

It was indicated that all of Canterra's drilling personnel and all senior personnel assigned by the drilling contractor (rig supervisor and toolpush) would have valid Second Line Supervisor Certificates. One person holding a Second Line Supervisor Certificate would be be on site at all times. The driller, or anyone performing his duties, would have a valid First Line Supervisor Certificate[8]. All crew members would be trained in the operation of BOP equipment.

Canterra said that all personnel assigned to the location, including the drilling representative would be required to have Canadian Association of Oilwell Drilling Contractors H_2S Alert certification. Additionally, all personnel regularly on site (rig crews, contract personnel) would receive H_2S alert training at the rig prior to drilling out of intermediate casing.

10.5.2 Views of Interveners

Mr. Murray, on behalf of the Bergen Group, indicated that the required staff for the well should include two drilling engineers, two geologists, two mud engineers, two drilling supervisors, and two safety supervisors. He said that they would be necessary to ensure all aspects of the drilling operation would be properly supervised.

10.5.3 Views of Board

The Board accepts the personnel and their qualifications as outlined by Canterra to be generally satisfactory providing considerable on-site effort is made to ensure continuous awareness of potential problems and their possible impacts, and that senior expert advice is available at all times. The Board gave consideration to requiring, if the well were licensed, that such senior experts be on site while the critical zone was open to the wellbore. It decided that such a requirement was unnecessary provided experts are reasonably available for immediate contact, and so long as on-site personnel clearly understand that such people must be contacted at the first sign of a problem.

The Board, if it issues a licence, would have to be satisfied at the time the final drilling plan is reviewed that the staffing is in accordance with the intent expressed by Canterra at the hearing.

10.6 Drilling and Kick-Control Procedures

10.6.1 Views of Canterra

Canterra stated that the drilling program, as discussed through the course of the hearing, showed that it was prepared for and able to handle overpressured zones but that the expected pressures in the Leduc are less than would exist using a water gradient. Should high pressures be encountered, weight material would be on site. The applicant stated that it did not expect the Nisku Formation to cause lost circulation problems but it would be prepared to case off the Nisku before drilling the Leduc should problems occur.

Canterra stated that when drilling below 3100 m, the drilling fluid would contain an excess of 30 kg/m^3 of lime

[8] A First Line Supervisors Certificate as issued to all persons who successfully complete the Canadian Association of Oilwell Drilling Contractors' course entitled Blowout Prevention & Well Control for First Line Supervisors.

in the system to act as a buffer should any H_2S enter the wellbore. Tests would be performed on a frequent basis to determine if H_2S had entered and, if it was detected, corrective action would be taken by controlling the pH, use of H_2S scavenger, and corrosion inhibitors. A minimum of 200 sacks of H_2S scavenger would be on site, in case a large quantity of sour gas entered the hole.

Canterra said that third-party involvement in the selection and maintaining of the drilling fluids was not necessary due to the expertise available within the company, which would be performing pilot testing on the fluids and quality control testing of products to ensure no substandard materials were used. The pit volume totalizer planned for use on this rig would be a state-of-the-art computerized system.

The applicant stated that corrosion rings would be used in the drill string and stressed steel balls would be present in the drilling fluid to monitor corrosion rates and the presence of H_2S. It also said that the time-delayed float valve proposed for this well had been tested to ensure it met the manufacturer's specification. It had been used in two previous wells drilled by Canterra and a third well drilled by another operator, and performance was satisfactory.

Canterra recognized the potential for human error and said it would undertake to reduce this factor as much as possible. It would be performing BOP drills prior to drilling out of surface casing and at least once each 7 days thereafter. Another practice drill would take place at 3100 m prior to drilling through the Rock Creek Formation. Additional practice drills would be performed as required to ensure all members of the crew were proficient in their duties. The "driller's method" of kick control, as taught at the Petroleum Industry Training School (PITS), would be posted on location. All supervisors would also be familiar with other kick-control methods.

Any drill-stem testing of sour formations would be done as closed chamber tests, and would be performed through the casing to further ensure a successful and safe test. The applicant confirmed that such drill-stem testing would occur only if absolutely necessary.

In response to concerns from Mr. Murray, Canterra stated that testing a barite plug in the field was impractical due to the high likelihood that a complicated fishing job would result. It contended that other methods existed to control underground blowouts and stated that in other drilling operations, such an occurrence had been controlled without the use of a barite plug.

Although it did not intend to test run a barite plug, Canterra said the materials required for the operation would be on site and the drilling supervisors would be knowledgeable of the procedure.

10.6.2 Views of Interveners

Mr. Murray, representing the Bergen Group, detailed a number of concerns respecting well control, such as the lack of information on the chemicals and procedures to be used for corrosion control. He suggested that all such information to be contained in the final drilling program should be made public so that independent drilling experts could review it.

He expressed concern with the lack of testing of drilling fluids because the 90 per cent H_2S at the downhole temperatures and pressures could greatly effect its chemical properties and render the pit totalizers useless.

Mr. Murray stated that it was essential to maintain the pH of the drilling fluid at 10 to ensure the integrity of the drill pipe should sour gas invade the wellbore. He agreed with the use of scavengers on a continual basis and expressed the view that the pH should be checked at least twice per 8-hour shift. Mr. Milo suggested that on such a critical well, the pH of the mud should be measured hourly.

Mr. Murray indicated that there could be some problems in circulating out or weighting up gas-cut mud, and he also questioned the means by which the applicant would handle possible lost circulation in the Nisku or abnormal high pressures of the Leduc Formation. He said that Canterra should test run a barite plug to ensure that it has the knowledge and ability to handle this method of well control.

Mr. Murray emphasized that the mud system should be maintained and frequently tested by qualified personnel to ensure that the drilling fluid properties are not affected by H_2S contamination. He stated that if H_2S invaded the wellbore, it could cause the drilling fluid to lose some of its carrying capacity, thus lessening the ability to prevent a kick from occurring.

Mr. Murray said that the applicant had little experience with the proposed downhole time-delayed float valve and that a critical well was not the place to be testing relatively new equipment.

10.6.3 Views of Board

The Board believes that drilling procedures and kick-control methods are of vital importance and must be totally satisfactory before it would allow this well to be drilled. The use of extreme caution in essentially all operations within the critical zone is probably the most effective way to reduce the chances of a blowout. Training procedures and BOP drills, as generally outlined, appear adequate to ensure crew proficiency, provided they are effectively carried out and that crew awareness is kept at a high level. If the well is licensed, the final drilling program will have to assure the Board that Canterra will conduct all

operations in the critical zone in a careful and demanding manner.

Generally, the Board agrees with Canterra's plans for the maintenance of the drilling fluid system, the use of excess lime and scavengers to neutralize H_2S should it enter the wellbore, the methods to circulate out a gas kick or deal with lost circulation, the pit volume totalizer, and the time-delayed float valve to be used.

Although the barite plug is one method of well control, the Board agrees with the applicant that a test run of this system could lead to undesirable hole problems, and notes that the material required to run such a plug would be on site if required.

If the well is drilled, the company may want to run a drill-stem test. While the Board believes that under proper conditions such a test could be safely carried out, at this time, it is not prepared to approve a test in the critical section. The reasons for this are the added risk, however small, of introducing well-control problems, or causing nuisance odours. Consequently, the Board would not allow a drill-stem test unless a subsequent application demonstrated a clear need and that the potential for problems would be small.

10.7 Detailed Drilling Plans

10.7.1 Views of Canterra

At various stages of the proceeding, interveners raised questions pertaining to specific technical items which were not addressed in detail in the application. Canterra, in response to many of these questions, indicated that the final drilling program would answer them. Canterra implied that it expected the Board to make decisions on such matters taking into account the comments of interveners. In response to a question, Mr. Martin indicated that very few parts of the final drilling program would be confidential.

10.7.2 Views of Interveners

Both the Bergen Group and Pioneer Lodge appealed to the Board indicating that in their view, the Canterra plans were not complete. Members of the public made general comments along the same line. This reference was to both the drilling program and the emergency evacuation plan.

In final argument, Mr. Miller, on behalf of the Bergen Group, requested that the community receive full and complete programs for the drilling of the well if the Board was prepared to grant the licence.

10.7.3 Views of Board

As already identified in other sections of this report, if it issues a licence, the Board would require Canterra to submit its final drilling program (and a final emergency procedures plan which will be discussed later) prior to commencement of drilling. Normally, these plans would be submitted to the Board and the Board staff would review them and then report to the Board who would make the final decision.

In this case, the Board believes it should go further if it issues a licence. The proposed well is expected to encounter a gas with 90 per cent H_2S; it is the first critical sour well to be reviewed at a public hearing since the Lodgepole Phase 2 report and critical well Draft Interim Directive were issued, and many concerns have been expressed by residents of the area. For these reasons, the Board would be prepared to establish a system whereby a copy of the final drilling plan, minus any proprietary information, would be made available for review by the public in the region. The Board would expect to receive comments from the public and would consider them in deciding whether the plans are adequate. Presumably, the public would wish to engage a drilling expert to comment and, if so, the Board would be prepared to pay reasonable costs.

10.8 Role of ERCB Field Staff if Well Licence is Issued

Little discussion took place at the hearing regarding the role of the Board staff with respect to the drilling of the proposed critical well should it be approved. The Board considers this to be an important matter and is aware that the staff, as a result of the Lodgepole Phase 2 report, is conducting a minimum of three inspections on critical wells. During these inspections, the staff ensures that all drilling equipment is properly functioning and that proper drilling and kick-control procedures are being followed.

As mentioned previously, the Board believes that the use of particularly careful procedures while drilling in the critical zone is one of the most effective ways of avoiding blowouts. To accomplish this, total crew awareness of potential problems and their consequences is necessary. The Board is of the view that a stepped-up role for its staff could assist in this regard.

Canterra indicated the likely time period in the critical zone would be about 30 days. (The length of this period is discussed further in section 11.) If the licence is issued, the Board would ask its staff to be present when the intermediate casing is drilled out, and thereafter to inspect the operations at least once per week while the critical zone is open. The Board would also require that Canterra report daily, by telephone to the ERCB area office. The report would indicate any problems that had been encountered, would confirm that daily inspections and drills were carried out, and, in order to facilitate an effective scheduling of

ERCB inspections, would generally identify planned operations during the coming 24-hour period. This requirement would be in addition to other functions required for critical sour wells.

The Board believes this increased staff involvement would be warranted given the particularly high expected H_2S content and the location of the proposed well.

10.9 Chances of a Blowout at the Proposed Well

10.9.1 Views of Canterra

During final argument, Canterra stated that "it and its predecessors have drilled over 1000 wells in the last 20 years, close to 300 of which were sour gas wells and have never experienced a major sour gas blowout during this drilling". Canterra also said that "no expert appearing as a witness in this hearing has said that this well cannot be drilled safely".

When questioned about the probability of a blowout at the applied-for well, Mr. Sawotin said that the 1 in 172 risk, as published in the Phase 2 Lodgepole report, was a historical figure but that there would be a major reduction in probability as a result of the new tighter regulations. Mr. Martin stated that the blowout probability for wells of unknown success would be less than 1 in 172, by the ratio of successful wells to all wells drilled.

Dr. Leahey also confirmed that he had used the 1 in 172 figure in his risk calculations and reduced it to 1 in 575 based on the assumption that only 30 per cent of wells drilling for sour fluids were successful.

10.9.2 Views of Interveners

Mr. Murray, for the Bergen Group, expressed the opinion that human error would be hard to eliminate and that this would be the key to eliminating blowouts. He referred to problems at other wells in the area and said that similar problems at the proposed well could make the risk of a blowout high.

Mr. Murray further commented that the industry should make a target of "zero blowouts" and unless this occurred "the government of the province is very likely to shut down sour gas drilling entirely in observance of adverse public reaction".

10.9.3 Views of Board

The Board has carefully reviewed the evidence presented as well as the statements made by participants regarding the probability of a blowout if this well were drilled. The Board believes that this matter is ultimately one of the most important considerations which has to be made when considering the application. The Board notes that when specifically questioned about the safety of drilling sour wells, Mr. Murray agreed, providing "parameters defined are met" that sour wells could be safely drilled.

The Board has reviewed the sour well blowout probability figure of 1 in 172 published in the Lodgepole Phase 2 report. The ratio cited is the number of sour well blowouts per successful well completed. Since not all wells which are exploring for sour gas find it, the historical number of sour gas blowouts per sour gas exploratory wells drilled would be much lower. Therefore, when the historical ratio of 1 in 172 is applied to an exploratory well, such as that proposed by Canterra, it must be altered to reflect the chances that the well would not be successful.

Canterra suggested the chance of success for the proposed well was 40 per cent, which, if applied to the historical ratio, would result in a blowout probability of 1 in 430.

The Board has not estimated a specific chance of success and thus an adjusted historical chance of a blowout for the proposed well because it believes that by far the most significant factor reducing the chances of a blowout are the special equipment and care to be taken in drilling. The 1 in 172, or 430, as adjusted, is based on history prior to the Draft Interim Directive which resulted from the Lodgepole inquiry. In this regard, the Board notes Mr. Murray's statements to the effect that he believed the proposed well could be safely drilled providing proper procedures were followed. The Board agrees with Mr. Murray and believes that this is the key item in reducing the probability of a blowout.

By applying closely supervised, well engineered plans, through the use of specialized equipment, and most of all by exercising extreme caution while in the critical zone, the probability of a blowout for this well, if it is licensed, would be reduced substantially.

The Board has reviewed the historical statistics regarding blowouts and their causes, using a typical fault tree network. It has assessed each of the causes of blowouts and attempted to estimate the impact on each of those causes of the special equipment and precautions that would prevail at the subject well. The statistics show that most kicks occur because of insufficient mud density or failure to keep the hole full while tripping, both of which reduce the pressure exerted against the formation at the bottom of the hole, swabbing of formation fluids into the wellbore by lifting pipe too quickly off the bottom of the hole, or lost circulation where the drilling fluids flow into a very porous formation. The Board believes that extra care and attention would have a major impact on these factors, particularly the failure to keep the hole full and swabbing which should be eliminated.

The statistics also show that the historical reasons why kick-control efforts have failed, resulting in blowouts, are equipment failures or improper control procedures. These kinds of problems cannot be totally eliminated, but prudently-designed equipment with adequate redundancy and a highly trained and well supervised crew, both of which would be specifically focused on during review of the final drilling plans, would greatly reduce the chances of a blowout.

A precise estimate of the probability of a blowout at any particular well is not possible. However, the overall conclusion which the Board has reached from its analysis is that the chances of a blowout at the proposed Canterra well would be significantly less than suggested by the historical data. Having reached this conclusion, the Board would not deny the subject application for a well licence on grounds that the well involves a high blowout risk. The Board emphasizes, however, that if there is any chance of a blowout, and there always will be, it would not allow the well to proceed if the impacts would be unacceptable, particularly from a public safety point of view. As a result, it will analyse those impacts in the following sections of the report along with actions which could be taken to mitigate them.

11 ACTIONS TO BE TAKEN IN CASE OF A BLOWOUT AND THE RESULTING IMPACTS

This section of the report, by necessity, details the circumstances that might exist if the proposed well was drilled and a blowout occurred. When the section is reviewed in isolation from the remainder of the report, it might give the impression that a blowout is to be expected. The Board emphasizes, as set out in the previous section, that this is not the case.

11.1 Actions to be Taken

11.1.1 Views of Canterra

Canterra submitted the general contents of an emergency response plan and said that if a licence is issued, it would prepare a detailed plan and review it with the public, seeking further input before it would be finalized. The key features of its proposed plan are described in the following paragraphs.

It would use a three-stage alert system.

- Stage 1 would be implemented if a kick occurred, and would involve notification and mobilization of company and government personnel to ensure they would be ready to act if a difficulty occurred in circulating out the kick.
- Stage 2 would be implemented if, when attempting to control the kick by circulating it to surface, a failure occurred in any piece of control equipment. At this stage, residents within the 4-kilometre (km) radius would be evacuated even though the well would not have blown out and efforts to control the kick would be continued.
- Stage 3 would be reached if the well was clearly out of control, at which time the complete emergency plan would be activated. Monitoring would take place and if levels of H_2S of 20 parts per million (ppm) or greater were detected beyond the 4-km radius, residents would either be evacuated or the well would be intentionally fired to convert the H_2S to SO_2.

Canterra said that if a kick occurred, there would likely be 2 to 3 hours before it reached surface and at least that much warning of an impending blowout should difficulties ensue.

The applicant said it has selected a 4-km planning zone as the largest practical zone. It would fire the well rather than try to deal with a larger area. It would use two mobile electronic H_2S/SO_2 monitors and would have them available at well site while drilling in the critical zone but did not see the need for monitors at individual residences.

Evacuation procedures would involve phone contacts and a mobile evacuation van to be stationed at the rig. A nurse would also be at the evacuation centre to advise the public. The evacuation centre would be the Town of Sundre (Sundre High School).

Appendix 4 shows the region surrounding the well, the proposed 4-km zone and the evacuation routes suggested by Canterra. In response to concerns respecting evacuation routes from the area, Canterra said it would construct two additional routes as shown in the appendix. Canterra said it investigated construction of a bridge across the river to the north but that such could not be justified because of the cost and the difficulty in providing road access.

The applicant stated that the on-site supervisor would have authority to fire the well if human life was in danger. This would be done automatically if an H_2S concentration peak of 75 ppm or a 30-minute average of 20 ppm was measured in an area that had not been evacuated, or if on any other basis, the on-site supervisor concluded that there was a threat to human life. Canterra said that a direction to automatically fire the well in case of a blowout would not be appropriate because damage from the ensuing fire might significantly extend the time needed to control the well.

The applicant anticipated no difficulty in igniting an uncontrolled release of 90 per cent H_2S gas which would be highly flammable within 20 to 30 feet of the exit point at the well. To ensure ignition would take place, Canterra proposed two ignition sources at the base of the rig which would be operated remotely via a flame ladder, with flare guns on site as a back-up.

11.1.2 Views of Interveners

The area residents individually and through the Bergen Group, the Pioneer Lodge, the Fallen Timber Group, and the Town of Sundre all expressed many concerns regarding the proposed emergency procedures plan. The residents considered the proposed 4-km planning zone inadequate and suggested that it meet the requirements of the Draft Interim Directive. They did not believe that the proposed ignition criteria were a suitable substitute for using a larger zone, and also questioned the use of Sundre as an evacuation centre because it is only some 9 km from the proposed well. Indeed, both the Town of Sundre and Pioneer Lodge said that the plan should consider the possible need to evacuate the Town of Sundre.

The local interveners were concerned that the number of evacuation routes in the area are limited, and may not be adequate to handle the volume of traffic during an evacuation. They referred to several situations where evacuation routes would take them past the well, for example, areas along the river where families outside the proposed emergency planning zone must enter the zone to escape the area, and the new proposed egress route for Pioneer Lodge which would be even closer to the well than the lodge is. The interveners suggested that a bridge across the Red Deer River is necessary to provide adequate egress from the area. Additionally, Mrs. Burton suggested that the new evacuation route to the north go through sections 17 and 18 rather than section 24.

The residents suggested that the applicant investigate a general telephone or other warning system because they foresaw great difficulty in ensuring that all people had been located and evacuated from the area. They said that procedures must be in place for searching for residents who cannot be reached by telephone, having in mind that the area includes dense brush and river valley flats, and that there could be deep snow at the time of an emergency. They also contended that one van was inadequate for assisted evacuations and should be increased to four.

Pioneer Lodge requested that adequate buses, with drivers familiar with the evacuation routes, be posted at the lodge while drilling the critical zone. It also asked that a contact person be posted there in case evacuation is required.

The local interveners pointed out that the emergency plan contains no provision for residents with health problems or for the elderly, who would find an evacuation traumatic. They requested a public health nurse to assist those who may be affected by the stress of an evacuation, and also asked that monitors be provided for the nearby residences.

The Bergen Group said that the plan should be expanded to address the concerns of local residents. They asked that they be given an opportunity to provide input to the plan, and to review the plan prior to approval by the ERCB. Pioneer Lodge stated that the plan should receive written approval from the county and Alberta Disaster Services prior to implementation.

The consultants for the Bergen Group presented evidence suggesting that there may be some difficulty in igniting the well. They said that even if ignition is possible, the ignition criteria proposed by the applicant is unacceptable because a decision based on monitoring data would not allow for a sufficiently quick decision.

11.1.3 Views of Board

Even if the possibility of a blowout is very remote, and regardless of the potential release rate, in this case the Board believes it crucial to public safety that means be provided to prevent a widespread dispersal of H_2S. To ensure this, the Board is of the opinion that if the well is licensed and drilled, and a blowout occurs, the most crucial action to be taken to protect the safety of the nearby residents is the ignition of the well.

Having reviewed the calculations and testimony of Dr. Leahey and Mr. Eichmaier regarding the distance from the wellhead at which the well effluent would be flammable, and the effluent exit velocity and the ignition temperature of H_2S, the Board is satisfied that the proposed ignition equipment would be adequate to ensure initial ignition of a release. However, the Board is concerned that the well might not remain on fire when first ignited due to the flow of drilling mud with the gas. Therefore, if the well is licensed, Canterra would have to satisfy the Board as part of the final drilling plan that it had devised a flare system with a remote fuel supply that would ensure that the well could be kept on fire.

Given the high H_2S concentration gas expected to be encountered, the uncertainty of the maximum potential H_2S release rate (as discussed in section 8), and the proximity and density of residents in the area surrounding the well (as shown in Appendix 4), the Board believes that any uncontrolled flow from this well would have to be ignited. This would convert the H_2S in the gas to SO_2, which, partly as a result of the thermal rise, would be more widely dispersed. The Board recognizes

that this is a strong position to take and that immediate firing of the well would result in damage to the wellhead equipment which could lengthen the time necessary to cap the well. The question of public safety, however, must take precedence.

The Board would be prepared to make an exception to the mandatory firing rule only when a small leak of gas is occurring and conditions are such that there is good potential for regaining control of the well. Conditions would have to be such that control operations are proceeding, the leak is under continuous observation, and firing would be possible immediately should a further equipment failure occur. Also, as set out later in this section, certain areas in the vicinity of the well would have to be evacuated, and downwind monitoring would have to be taking place with the results showing no H_2S concentration greater than 20 ppm in any unevacuated area.

The Board has considered specifying the maximum time period during which a small leak would be allowed to flow without ignition, provided all the above conditions are met. Variables such as the location of the leak, the volume of gas escaping, and the condition of the control equipment make such a predetermination impractical. If such an event occurred, the necessity to ignite the leak would be under continuous review.

The Board considers the question of ignition criteria to be of basic importance in terms of all other actions that would be taken and of the impacts that could result from a blowout. Accordingly, if it issues the licence, the Board will set out the ignition criteria as a specific condition as follows:

A Responsibility for ignition will be delegated to and rest with the designated Canterra representative on site who will cause the well to be ignited under the conditions set out in clause B.

B The well must be ignited as soon as all personnel working at the site can be cleared to a safe distance under any of the following conditions:

1 The well is experiencing an uncontrolled flow[9] and the well effluent has reached the surface.

2 The well is flowing small volumes of sour gas to surface and is partially controlled but safety of residents cannot be assured because:

(a) evacuation of residents within 1 km (the high-level emergency zone described later) has not been accomplished, or

(b) monitoring results indicate H_2S levels that exceed 20 ppm in unevacuated areas, or

(c) monitoring is not taking place due to some unforeseen circumstances, such as weather.

With respect to the ambient air monitoring to be conducted during the critical phase of the well, the Board believes that two mobile electronic monitoring units should be stationed at the rig during the critical phase of drilling so that they can be positioned downwind to commence monitoring at the first indication of a problem. With the ignition requirements set out earlier and the alert and evacuation criteria set out in the following sections, there is no need for monitoring units stationed at individual residences.

With respect to the three-stage alert and evacuation program proposed by Canterra, the Board sees merit in such an approach but believes that it should be amended from that submitted. The revised alert stages would be as follows:

- Stage 1 would be implemented if a kick[10] occurred and would involvenotification and mobilization of company and government personnel to ensure they would be ready to act if a difficulty occurred in circulating out the kick. Additionally, electronic monitoring equipment which would be required at the rig during the critical period would be dispatched to the downwind areas for possible monitoring.
- Stage 2 would be implemented if, when attempting to control the kick by circulating it to surface, a failure occurred in any piece of control or circulating equipment. At this point, the full sour gas response emergency plan would be implemented in order that all personnel and facilities would be in place should an uncontrolled release occur.
- Stage 3 would be reached if a small leak of sour gas occurred and conditions were such, as described previously, that the leak would not have to be ignited. If the leak was ignited, it would almost certainly lead to complete loss of control and a Stage 4 situation.
- Stage 4 would be reached if the well was out of control at which timeit would be ignited if it was not already on fire.

Having set out the ignition criteria and the four-stage alert system required, the Board will next address the question of emergency response planning areas. The Board does not fully agree with the H_2S release rate calculated by Canterra, nor does it consider the 4-km

[9] "Uncontrolled flow" and other terms are defined in Appendix 6.

[10] Also includes any other severe drilling problem such as lost circulation or stuck pipe.

planning area around the well fully adequate. At the same time, given the unusual ignition requirements that would in this case be attached to any well licence issued, the Board recognizes that the emergency planning area does not have the same meaning as is normally the case.

In this particular situation, the Board believes a series of concentric areas, illustrated on Figure 2 (Appendix 4), should be established around the proposed well, each of which would be part of the emergency planning area. They would not, however, all require the same level of emergency activities.

An inner ring of 1-km radius closest to the proposed well would be established as the high-level emergency zone. Next would be medium-level emergency zone comprising the area between the high-level zone and a 4-km radius circle. The 4-km circle would be extended to the northwest of the well to the Red Deer River in the northern part of section 10, section 15, section 22, and section 23, all in township 32, range 6, west of the 5th meridian. These sections contain several residences without egress from the area except to go past the proposed well site.

The final concentric ring of the emergency area would extend to 8 km, double the distance to the 4-km medium-level emergency zone. This low-level emergency zone from 4 to 8 km from the proposed well is considered an added precaution in view of the requirement that an uncontrolled release would have to be ignited. Although somewhat irrelevant in view of the requirement for ignition, the 8-km distance is also the approximate distance to the calculated 100-ppm H_2S isopleth under worst conditions, without ignition, at a release rate of 6 m^3/s. The Board believes it important to note that the isopleth calculation assumes worst conditions and is very conservative in nature.

The requirements that would apply to the three zones are summarized in Table 2 and would be generally as follows:

High-Level Emergency Zone (1 km) – Zone 1

Residents within this area would be provided with an H_2S information package, would be visited to ensure they understand the program, and would be kept fully aware of activities at the well during drilling of the critical zone. In the case of a kick or other severe drilling problem (Stage 1 alert) they would be advised so that an evacuation, if necessary, could be quickly accomplished. The evacuation would take place as a first priority off-site action if any problem occurred during efforts to control the kick (Stage 2 alert). Even though immediate ignition would be required in case of a blowout, or of a leak if public safety could not be assured, the evacuation would take place as an extra precaution because of the proximity of these residents to the well and uncertainties that always accompany emergencies. The zone would have to remain evacuated until the well was fully under control or, if the well was on fire, until monitoring for SO_2 and other relevant information clearly demonstrated that there was no safety reason for keeping the area evacuated.

Medium-Level Emergency Zone (beyond the 1-km high-level zone to approximately 4 km) – Zone 2

Residents in this area would receive the H_2S information package and would be visited to ensure they understand the program. They would be notified if a problem occurs during kick-control procedures (Stage 2 alert) and any particularly sensitive individuals (the ill, elderly, or very young) would be evacuated. These individuals would have to be identified as part of the detailed emergency planning process. At this particular stage, which would be prior to any actual blowout, the Board believes that other persons who wished to leave the area should also be evacuated. This would be done primarily for the peace of mind of the individuals because with the ignition requirements as discussed previously no threat to life should exist. The only times that evacuation would be essential is if the well was blowing out of control (Stage 4 alert) and in the extremely unlikely circumstances where either it could not be ignited or kept on fire or the equally unlikely case where it was burning but monitoring results showed high levels of SO_2. For this purpose, a high level of SO_2 would be 1 ppm for 2 to 3 hours or 0.3 ppm average over 24 hours.

In the event of a small leak of sour gas (Stage 3 alert) where the well is not out of control and monitoring shows no threat to human life, all residents in this zone out to about 4 km should be evacuated to provide Canterra with additional time to try to fully control the well before igniting it. The object in this case would be to quickly control the well and avoid a prolonged emission of SO_2 from a burning well. Following an evacuation, the return of evacuated people to their homes would depend on well-control operations and the results of monitoring.

Low-Level Emergency Zone (beyond 4-km medium-level zone to 8 km) – Zone 3

Residents in this zone would receive the H_2S information package. There is little possibility that special action would be required for people in this zone except for sensitive individuals who should have been identified during the planning process. They would be evacuated if any problems were encountered during kick-control operations (Stage 2 alert). Also, if the problems were not successfully overcome and the well blows out (Stage 4 alert), those in this zone who wished to leave would be

TABLE 2 SUMMARY OF EMERGENCY PLAN BY ALERT STAGE AND ZONE

Alert Stage	Well Condition	Zone 1 1-km radius	Zone 2 4-km radius and northwest	Zone 3 8-km radius	Additional Action
0	No problem	Information package + visit + awareness of activities	Information package + visit	Information package	–
1	Kick or other severe drilling problem	Evacuation alert	–	–	Notify and mobilize company and government personnel. Dispatch air monitors downwind.
2	Control equipment failure while circulating kick	Evacuate	Information alert. Evacuate sensitive people and those who wish to leave.	Information alert. Evacuate sensitive people.	Initiate sour gas release emergency plan.
3	Small sour gas leak – not ignited	Evacuated	Evacuate remainder of people.	Evacuate those who wish to leave.	Monitor downwind area and ignite if public safety cannot be assured.
4	Uncontrolled flow	Evacuated	Evacuate* if burn not continuous or if SO_2 levels high	Evacuate if burn not continous or if SO_2 levels high	Ignite immediately

* Zone 2 may already have been evacuated if a Stage 3 alert had been in effect.

evacuated. As would be the case for Zone 2, in the highly unlikely event of a blowout where it was not possible to keep the well continuously on fire, or where monitoring results showed high SO_2 readings as defined above, Zone 3 would be evacuated.

The previously described evacuation requirements for the emergency response area are in addition to those provincial guidelines for action regarding H_2S established by the Alberta Provincial Board of Health.

The Board has considered the matter of the number of evacuation vans and believes that the availability of four vans to assist with evacuation should be sufficient. Canterra has agreed to supply buses with drivers knowledgeable of the evacuation routes to Pioneer Lodge while drilling in the critical zone. A contact person is also to be supplied. The Board believes that these measures would be adequate.

The Board notes that Canterra has agreed to supply the services of a public health nurse during the critical phase of the well, in order to counsel or assist the elderly or those with health problems.

The Board recognizes the concerns expressed by the residents regarding the routes for evacuation from the area. The Board also notes that many of the residents must travel toward the well in order to evacuate, especially in the areas north and northwest of the well. The applicant has agreed to construct or provide for egress which would maintain more separation distance between residents and the well during an evacuation. These routes are shown on Appendix 4.

The Board has reviewed the available routes, those proposed by Canterra, and the concerns expressed by the interveners, including those respecting the need for a new bridge north across the river. Because of the strict

ignition criteria and the reduced reliance on evacuation for safety, the Board is satisfied that Canterra's plans are acceptable. Even though the Board believes that it is unlikely that residents in the low-emergency zone to 8 km would ever have to be evacuated, it believes the company's final plan should include specific egress information for those areas where there are limited options.

The Board wishes to emphasize that a comprehensive review of the final emergency procedures plan will be done prior to its approval. In addition, in this case, the Board is prepared to establish a system which provides for comments from the public to the Board on the final plan. The Board would expect that this input could be accomplished primarily through meetings with residents in the area. It would be prepared to defray the costs of an expert adviser for the residents if they so desired.

11.2 Plans for Capping Well

11.2.1 Views of Canterra

Through rebuttal evidence, Canterra stated that in its opinion the prefiling of well capping procedures would be a hypothetical and largely futile exercise. The applicant indicated that if the well blew out, the actual capping procedures would depend on many variables which would be impossible to predict in advance. It said that the structure of its organization would allow for the effective handling of control operations and planning for a relief well should such be needed.

Canterra expressed, the opinion that a relief well, if needed, could be commenced in 7 to 14 days following a blowout. The applicant also stated that the surface location for the relief well would be prenegotiated.

11.2.2 Views of Interveners

Mr. Murray, for the Bergen Group, expressed concern that should the proposed well blow out it would be very difficult to regain control. It was suggested that very little experience exists worldwide in the procedures to be used to cap a well with 90 per cent H_2S, whether it was ignited or not.

Mr. Murray expressed an opinion that the drilling of a relief well had as much a chance of being unsuccessful as it did of being successful. A concern was expressed that obtaining the licence for the relief well could be a lengthy process if a hearing was required.

11.2.3 Views of Board

While the Board is confident that the proposed well could be drilled without problems, it recognizes the potential problems of capping a wild well. However, it agrees with the applicant that little would be gained by preplanning in detail such an operation. Rather, the planning efforts should focus on preventing a blowout. However, an emergency response plan should lay out the lines of authority and steps to be taken to ensure that control operations would be promptly implemented.

The Board also recognizes the potential problems of drilling a relief well. Should such a well be required, the licensing and initiation of the drilling operation could be done in the time frame suggested by the applicant.

11.3 Impacts of a Blowout

As indicated in the previous section, if the proposed well was licensed and drilled, the Board believes the probability of a blowout would be very low. However, before it decides whether a licence should be issued, it considers it necessary to evaluate how serious the impacts of a blowout would be. The previous subsection deals with numerous actions to be taken in the event of a blowout. Many of them would be to mitigate the impacts, and the basis for this section of the report is that the actions would be taken. The most crucial action in terms of potential impacts on the public is the ignition requirement which the Board would impose on Canterra if the licence is issued.

11.3.1 Views of Canterra

The applicant stated that the impacts of H_2S on residents in the area would be minimized by the proposed ignition and evacuation procedures. Canterra said that it would initiate an evacuation if there was a failure of kick-control equipment during any kick-control operations, and also would ignite an uncontrolled release at an early stage.

The company's risk consultant, Dr. Leahey, presented an analysis to demonstrate that the residents would be exposed to only a very low level of risk from H_2S if a blowout occurred and the proposed evacuation and ignition procedures were followed. He also expressed the opinion that there would be no adverse effects from levels of H_2S to which residents might be exposed. Dr. Leahey did, however, agree that the toxicity assumption in the analysis may not be appropriate if the area residents contain a particularly high proportion of persons more susceptible to H_2S than the average. He also presented modelling results that showed a possibly worst-case rapid movement of the plume in 27 minutes to Pioneer Lodge and 74 minutes to the Town of Sundre. Dr. Leahey acknowledged that H_2S will, in some meteorological circumstances, tend to move along the ground and to disperse less quickly in low areas.

The applicant's view regarding emissions from the well subsequent to ignition was that evacuation due to SO_2

should not be required, nor would any hazard to health occur. Dr. Leahey said, based on the flammability of H_2S, that 100 per cent conversion to SO_2 is a reasonable assumption and H_2S should not be of concern after ignition. He indicated that SO_2 is of similar toxicity to H_2S, but the large thermal rise from the combustion of the plume would produce better dispersion and result in much lower ground-level concentrations than for H_2S from the unignited plume.

Dr. Leahey presented the results of dispersion calculations for the ignited plume, which predicted concentrations of SO_2 below the occupational exposure limits (OEL). He predicted, because the model is conservative, an actual maximum SO_2 concentration of approximately 0.06 ppm with maxima occurring on approximately 12 days, assuming a possible 120-day blowout period. He expected that such SO_2 concentrations would be below the odour threshold but above the taste threshold.

Canterra agreed to gather and disseminate information on the health effects of low levels of SO_2 to the local residents. Should the area be subjected to low level concentrations of SO_2, Canterra would seek information from any residents perceiving health effects.

The applicant presented a panel of experts to address the impact of an uncontrolled release on the local water systems, both surface water, including the Red Deer River, and the shallow aquifers which are the water supply for local residents. Members of the panel testified that a very minimal impact, possibly below the present range of possible measurement, would occur. They discussed such factors as the low solubility of H_2S, the low expected atmospheric concentrations of SO_2, the high buffering capability of the local soils, and the dilution effect due to the large size of the local aquifer to support their view.

When questioned regarding the impacts of the Lodgepole blowout on water, the experts attributed the groundwater effects to condensate, and indicated that the proposed well effluent is not expected to contain condensate. The experts did not foresee any health impacts from use of the local water nor any change in water availability as a result of drilling the well, even if it blew out. In addition, Canterra made a commitment to monitor all water wells within a 4-km radius of the proposed well, including sampling and flow testing.

In response to concerns of area residents that the well be drilled during the time of year when impacts would be minimized, Canterra said that it had no preferred season to drill the well, only that it would like to begin as soon as possible.

The applicant stated that compensation would be paid where the company was found responsible for damages. This was agreed to for cases such as evacuation expenses, loss of livestock, and loss of land value including vegetation. The applicant did not consider posting of a performance bond necessary.

11.3.2 Views of Interveners

The Bergen Group and other local interveners expressed concern regarding the toxic levels of H_2S that would be released by a blowout of the proposed well. The level of risk associated with the facility was felt to be unacceptable. They questioned some of the assumptions made in the risk calculations, such as the concentration at which H_2S is fatal, and the use of flat topography notwithstanding the Red Deer River valley. The residents also questioned whether adequate consideration had been given to those who might be more sensitive to H_2S, the elderly, the very young, and those with health problems. The Town of Sundre expressed concern that the residents of Sundre could be exposed to potentially lethal concentrations of H_2S if an uncontrolled release occurred. It also indicated a concern regarding the general environmental impact of the well, and requested that an environmental impact assessment (EIA) be prepared prior to spudding. An additional concern was voiced for the safety of the livestock, which would be left behind if it was necessary to evacuate the area.

Residents also expressed the view that discomfort from the odour of H_2S is an important consideration, and that a commitment should be made by the applicant to ignite an uncontrolled release after some maximum time period.

Mr. Cloakey expressed the view that people and animals in the Bergen area exhibited health symptoms from both the H_2S and SO_2 emitted during the Lodgepole blowout. He felt, as a result, that the 20-ppm evacuation criteria for H_2S is too high, as it does not take short-term peaks into account, and relates to workers – not those who may be more sensitive.

The local interveners also expressed concern regarding possible health impacts from the low levels of SO_2 that would result from ignition of the proposed well if a blowout occurred. The residents were concerned about the health effects reported and experienced during the ignited phases of the Lodgepole blowout. Several said that a large proportion of local residents had moved to the area because of concerns for health, and that the area might contain a higher than average number of more sensitive people.

Mr. Grimstead expressed concerns regarding SO_2 and based them on his experience with discomfort from emis-

sions from existing wells in the area where sour gas is burned.

The local residents questioned whether existing studies into the health effects of low level emissions of H_2S and SO_2 were conclusive. They pointed out that causes of illness are often difficult to determine, and that chronic illness from emissions would occur for a long period of time before the cause could be identified. Mr. Grimstead pointed to an absence of information available regarding the health effects of H_2S and SO_2 at low levels, and recommended that more studies be done. Mrs. Halvorson also noted the lack of such information and Dr. Bauman expressed concern that no medical witness was present to discuss the health effects of SO_2 or H_2S.

The bulk of the concern regarding the impact of the well on potable water supplies in the area was expressed by the Red Deer Regional Planning Commission (Commission), on behalf of the City of Red Deer and other communities, and the Town of Sundre. The Commission was concerned that an adverse impact on the quality of water in the Red Deer River would affect the water supply of a large number of downstream communities. It stated that even a minimal impact would not be acceptable, but did not define what would be considered a minimal impact. The Town of Sundre also expressed concern with potential impacts on the Red Deer River.

Mrs. Burton requested that the applicant expand the radius of the proposed testing program for water wells in the area.

The Bergen residents were concerned that the impact of a blowout would be more severe during certain critical periods in their farming operations. The period of most concern was during calving and foaling from January to May and during the summer when outdoor work and recreation would make evacuation more difficult. Pioneer Lodge said that its period of lowest use was in late fall. It gave June as a second choice, provided that drilling would be completed before July. Mrs. Halverson gave June and November as preferred months for drilling. Mrs. Worobetz had concerns year round, but particularly in winter when the area experiences heavy wet snow and evacuation may be impossible, in spring during calving, and in early summer during foaling and breeding.

There appeared to be general agreement among the local interveners that if the well had to be drilled, October and November would create the least impact on them and their operations in the area.

Many of the area residents questioned Canterra regarding compensation for various losses and damages that might result from a blowout. These included loss of and injury to livestock, loss of land value including damage to vegetation, evacuation expenses, and loss of income due to a disruption of normal activities. The residents also made several suggestions as to how such losses might be compensated. The Bergen Group requested that the applicant provide a written guarantee of compensation for any damages that might occur. Pioneer Lodge recommended that a performance bond be posted to compensate residents.

11.3.3 Views of Board

The Board recognizes the concern of the local residents regarding the toxic levels of H_2S that could be released from a blowout of the proposed well. The Board has examined the risk calculation provided by Dr. Leahey, and although it believes the calculation is as accurate as current technology allows, it does agree with the interveners that there is a significant degree of uncertainty in many of the inputs to the calculation. It is for this reason, coupled with the maximum potential release rate and the number of residents in the area, that any blowout must be ignited immediately unless there is partial control of a small flow and regaining full control is imminent and nearby residents have been evacuated (as under conditions defined earlier). In these circumstances, that is with a mandatory ignition of any blowout, the Board believes that the impact of H_2S on the public or the surrounding area would not be significant.

The Board has examined the SO_2 dispersion calculations provided on behalf of the applicant by Western Research. The predicted concentrations indicate that the Alberta air quality standards for SO_2 (Clean Air Act Maximum Levels Regulation) may be exceeded if certain adverse atmospheric conditions existed. However, under the worst of these conditions, the predicted SO_2 concentrations are approximately half of the maximum allowable under Occupational Health and Safety Act, Chemical Hazards Regulation. Although the Board believes that it is highly unlikely that evacuation due to high SO_2 would be necessary if a blowout occurred and the well was ignited, SO_2 concentrations under adverse conditions could make it necessary to evacuate some areas and therefore monitoring would be required.

Canterra has asked that in such an event, it be informed of any adverse health effects from SO_2 experienced by residents. The Board recognizes that sensitive individuals could experience difficulties even though concentrations would be low, and would expect such effects to be promptly investigated by the local medical authorities, and such residents be evacuated from the area at Canterra's expense.

The Board is satisfied that minimal impact on the area's surface and groundwater is to be expected if a blowout occurs. Little or no condensate is expected in the effluent

of the proposed well, and the majority of negative impacts on water systems seen in previous blowouts were due to condensate.

The Board also agrees with the applicant's intention to perform water quality and flow testing on all water wells within 4 km of the proposed well. The Board sees no necessity of extending the tests beyond that distance because it is satisfied that such outlying wells would not be affected.

The Board agrees with the interveners that there is presently a lack of data regarding the health effects from long-term exposure to low levels of H_2S or SO_2. Even though the matter of air quality standards is beyond the jurisdiction of the ERCB, the Board knows that the existing ambient air quality standards were set in order to prevent health effects. Indeed, the standards imposed are actually nuisance standards rather than health standards and are equal to the most demanding in the country. It should be noted that occupational health standards allow sustained H_2S levels of 10 ppm for 8 hours per day which is 1000 times higher than the level provided for in provincial air quality standards.

The Board notes the concerns expressed by the local residents regarding the timing of the drilling of the well and their contention that if the well must proceed, it should be drilled at the time of year that would present the least negative impact on the surrounding residents if a problem occurred. Comments were made regarding calving and foaling in the spring, outdoor work and recreation during summer, and difficulty with evacuation due to heavy snow in winter. There appeared to be some consensus among local interveners that the most appropriate time would be during the late fall. The applicant expressed no difficulty with drilling at any particular time of year, but urged that it be allowed to proceed as soon as possible.

The Board has analysed the schedule that might be followed if it was to issue a well licence in early January 1985. The Board estimates that the elapsed time required to prepare final drilling and emergency response plans, have them reviewed by the Board and the public, obtain Board approval of the plans, contract for and move in a rig, and drill to the critical zone and set intermediate casing might take 6 or 7 months. This would mean operations in the critical zone in the July or August period, and an imposed delay to late fall would translate into about 3 months. Given the circumstances that this would be the first very high H_2S well drilled subsequent to a public hearing since the release of the Lodgepole inquiry report, and the many concerns expressed by residents of the area, the Board does not consider that the approximate 3-month delay would be unreasonable. Accordingly, if it licenses the well, the Board would require that the timing of the drilling be such that the critical zone would be open only during October or November.

On a related matter, since the only period of serious concern is when the critical zone is open, the Board will require Canterra to investigate ways in which it could reduce that time. It believes that the 30-day period could be reduced and would require the company to give reasons in the final drilling plan as to why each proposed operation in the critical zone is neccessary.

Regarding the matters of compensation and a performance bond, the Board has reviewed the legislation under which it operates and the Canterra application was filed. On the basis of the review, it has serious doubts as to whether it would have jurisdiction to condition a well licence with a requirement for the posting of a performance bond. This, coupled with the size and resources of the applicant company, Canterra, the legal obligations which the licence would impose on it to control any blowout and to protect the public, and its undertaking at the hearing to accept financial responsibility for any damage that was caused by its operations, results in a conclusion by the Board that a performance bond condition to the licence would not be appropriate.

The Board does understand the concerns expressed by certain residents of the area regarding possible costs to them of impacts should a blowout occur. Comments from some of the interveners appeared to recognize that if a blowout occurred and financial impacts were proven, a settlement would be made. Their concerns, however, apparently relate to the burden of proof being on the public, the relative costs of that burden, and the lengthy delays that would likely occur. Concern was also expressed that the nuisance effects of a blowout, and indeed the fear that one might occur and the resulting pressure and anxiety that residents of the area would be subjected to if the well was drilled, were items that should be compensated for but would not be under the existing civil liability system.

Suggestions were made that Canterra be required to carry blowout insurance. This seems to imply an expectation on the part of some residents that a form of no-fault third-party-damage insurance would eliminate deficiencies which they saw in the present system. The Board is not certain that this would be the case, but notes that the Lodgepole Blowout Inquiry Panel recognized a possible problem of this nature and recommended study of the matter by the ERCB, industry, and concerned government departments. Such a review is currently under way.

11.4 Summary Views

Having reviewed all of the evidence concerning actions to be taken in the event of a blowout and the resulting impacts, the Board concludes that the impacts of a blowout would not be disasterous to the public provided the appropriate actions are adequately planned for and properly executed if a blowout occurs. The Board cannot overemphasize the importance it places on the actions which must be taken in such an event, particularly with respect to ignition of the well. As indicated in the preceding section, the Board is satisfied that the applied-for well can be drilled safely, however, even in the unlikely event of a blowout, it believes resulting impacts can be minimized and kept to an acceptable level.

12 TEST PHASES AND LIKELIHOOD OF FURTHER DEVELOPMENT

12.1 Testing

12.1.1 Views of Canterra

The applicant said that an as-yet undetermined period of flaring would be required for the testing of the proposed well. It did not believe that further testing of the existing Bearberry well would provide adequate information as to the capability of the proposed well.

Several alternatives to flaring which are presently available, including on-site processing of the gas, had been examined by the applicant but dismissed as impractical. It did agree to consider the possibility of piping the test production to a more remote location for flaring.

Although Canterra has not yet been able to form an estimate of the period of testing that would be required, it agreed to minimize the period of flaring, and to dilute the well effluent with fuel gas, if necessary, to meet the SO_2 ground-level standards.

12.1.2 Views of Interveners

The Bergen Group and other local interveners expressed concern with odours that might result from the testing of the well. They related past unpleasant experiences with odours from the plant or wells in the existing Harmattan-Elkton Field, and expressed concern regarding possible health effects from exposure to the plume, especially to more sensitive individuals.

The Bergen Group recommended that all steps possible to reduce odours be taken, and that all odour complaints be handled immediately. Mr. Grimstead stated that if the existing facilities in the area are presently meeting the SO_2 ground-level air quality standards, then the standards are too lenient because he has experienced discomfort from odours from them.

12.1.3 Views of Board

Since the present application deals with a licence to drill the proposed well, the Board is not in a position to make a decision respecting possible testing. If the well is drilled and such an application is made in future, the Board would examine in detail the matter of flaring effluent from the well.

An application, if made, would have to deal with possible alternatives to flaring, the period of flaring and steps to minimize it, steps to prevent a violation of the H_2S and SO_2 ground-level standards, the extent of planned downwind monitoring, and actions to be taken in the event of a violation or an odour complaint.

12.2 Likelihood of Further Development

12.2.1 Views of Canterra

Canterra said that if the proposed well was successfully drilled, the well effluent would likely be transported via pipeline to the Ram River gas plant and suggested three possible pipeline routes. Canterra acknowledged that sulphur plugging can be a critical problem in gathering systems but stated that it has been successful in solving this problem in other high H_2S wells. It stated that the amount of sulphur solvent in the pipeline along with that in the produced fluid would be sufficient to dissolve any additional sulphur that might come out of solution. Canterra also said that the solubility of sulphur is significantly higher in liquid than in gas and it would therefore keep the fluid in its liquid form to reduce the risk of precipitation in the pipeline.

Canterra submitted that its preference for processing the gas from the well would be at the Ram River plant because excess capacity would be used and the regeneration of the solvent at Ram River rather than at the well site would be more desirable from an environmental point of view. Canterra stated that if it had difficulties transporting the fluid to Ram River, its second option, which it acknowledged as possible, would be to build a gas plant in the area. It also said that there was a possibility of more wells being drilled in the area, some by other operators, and their preference for processing the gas is completely unknown.

Canterra submitted that if the proposed well is completed, the production facilities at the well site would probably include a separator, a utilities package, an enclosed sulphur solvent system, a supervisory control system, and a back-up power system. The enclosed sulphur solvent system should prevent the rather odoriferous solvent from escaping and annoying residents in the area. Canterra acknowledged, however, that there could be occasions where it would be necessary to truck solvent to the well site and odours might escape.

The well-site equipment would be computer controlled by a system located on the lease but the operation would be remotely monitored and inspected daily by a company representative. Thermal detectors located at the well site would, in the case of fire, set off an alarm in the control room at the Ram River plant and the well could be shut in remotely. In the event of a power failure, the battery pack planned for the well site would have enough capacity to run the instrumentation on the lease for a few days. Canterra stated that there would be no continuous emissions from the well site, although there could be occasional leaks which, upon being detected, would be immediately fixed.

Canterra said that in the event a licence is issued and a successful well is drilled, it is prepared to accept the risk that it might not receive approval for the testing, pipelining, or the processing of the gas.

12.2.2 Views of Interveners

The Bergen Group stated that processing the gas at Ram River would be far superior to the well site, provided the well effluent could be maintained in the liquid phase while transporting it to the plant. The group stated that regeneration of the solvent and processing of gas at the well site could cause H_2S and SO_2 pollution problems.

The Bergen Group also identified a number of concerns it had even if the gas was processed at Ram River, including odours from the transport and use of solvent, corrosiveness of the solvent/liquid H_2S mixture, phase separation and liquid hold-up in the gathering system, the risk of pipeline rupture, design of the block valve spacing, and flaring under normal and emergency conditions.

12.2.3 Views of Board

The Board does not have applications before it for possible subsequent phases of the project and accordingly cannot deal with them. It is looking at these matters in only a general sense in that it would likely not issue a well licence if evidence clearly indicated that production from the well was impossible. At the same time, it is necessary to emphasize that approval of the well licence application does not assure that subsequent facility applications would be approved.

Generally, the Board is satisfied with the explanation of possible future development in connection with the proposed well. The Board believes that there are a number of technical matters which would have to be dealt with at the appropriate stage of development but there is a reasonable chance that acceptable solutions would be available. The Board expects that a well of this nature would be state-of-the-art as far as remote operation, equipment redundancy, and security is concerned.

It generally appears that a suitable pipeline route could be found and this would have to be evaluated along with its technical design and operation at such time as an application is made.

The Board recognizes that the successful drilling of the subject well could lead to licence applications for other wells in the area. The issuance of a licence for this would not necessarily mean subsequent applications would be approved. This would depend on the assessed merit of the applications at the times they were made.

13 FINDINGS

The Board, having regard for its responsibilities under the legislation, and its reviewing of the extensive evidence presented, finds as follows:

1 Canterra has leases in the area of the proposed well and the right to explore for minerals.

2 There is a good chance that the proposed well will prove up reserves of very sour natural gas and provide an opportunity to test, on a site-specific basis, the proposed technology for producing such reserves.

3 The well should not be drilled if other tests in the province of the production technology take place and suggest that there is little likelihood of it being successful.

4 It is difficult to estimate the maximum potential H_2S release rate for the proposed well, but on the basis of a test at the nearby Bearberry well, and using a conservative approach for purposes of planning for the safety of the public, the H_2S release rate could range from 6 to 15 m^3/s.

5 There are no unique or serious problems to be expected in the "non-critical" portion of the proposed well, above 3775 m, and intermediate casing will be set at that point. Care is necessary to preserve the integrity of that casing because it could be crucial if problems developed while drilling in the potentially high H_2S section of the well.

6 The geological prognosis does not suggest that particularly serious problems, such as overpressured zones, would be encountered while drilling in the Nisku and Leduc formations, the critical section of the proposed well. Nevertheless, caution is required because of uncertainties as to what will be encountered.

7. The Board is satisfied with the casing program planned for the proposed well.

8 The Board is generally satisfied with the BOP equipment planned for the proposed well; however, inspection and testing of the equipment is very important and must be detailed for further review in the final drilling program.

9 The overall plans respecting the mud system are satisfactory but more detail will be required in the final drilling program. Additionally, a volume of ready-mixed mud equal to 150 per cent of the volume of the hole should be available at the time the intermediate casing is drilled out.

10 The Grade E drill pipe planned by Canterra is acceptable, provided care is taken respecting inspections and maintenance of it. Details respecting these matters would be required in the final drilling program.

11 The proposed kick-detection equipment is generally satisfactory. The use of such equipment, however, is equally important as the equipment itself, and both of these matters should be further detailed in the final drilling program.

12 Detailed procedures are required to ensure that all equipment which could come in contact with H_2S at the proposed well would meet H_2S specifications. The final drilling plan would have to detail the manner in which this would be done.

13 Canterra's plans respecting safety equipment and procedures appear reasonable; however, the detailed plans to be included in the final drilling program will be reviewed with the OH&S Division of Workers' Health, Safety and Compensation to ensure such is the case.

14 Plans respecting supervisors and other rig personnel are generally satisfactory but the final drilling program must elaborate on procedures that will be used to ensure that the well-site personnel are totally aware of the importance of avoiding problems, and to ensure that experienced advice is readily available and will be accessed when needed.

15 Drilling procedures and those planned to control a kick, should one occur, are of vital importance in terms of avoiding a blowout at the proposed well. Canterra's plans in this respect are generally satisfactory but require further attention in the detailed drilling program, particularly with respect to staff training and drills to ensure that procedures are fully understood and that caution will be exercised in all important operations.

16 A drill-stem test of the critical zone at the proposed well should not be conducted unless Canterra can demonstrate a clear need for such a test and that potential problems can be adequately handled.

17 The final drilling program should be made available to the public for review so that the public may submit comments to the Board. The Board would be prepared to defray reasonable costs for a drilling expert to advise the public of the Bergen area in this regard.

18 ERCB involvement in and inspections of the drilling operations at the proposed well should be increased over that which is normal. Such inspections should occur at least weekly while drilling in the critical zone, and during the same period, Canterra shall report daily to the ERCB field office respecting its progress and any problems encountered.

19 The chances of a blowout at the proposed well would be greatly reduced when compared to historical statistics respecting sour gas blowouts because of the extra precautions to be taken and the special equipment to be used. Although a precise estimate of the chances of a blowout at the well is not possible, it would be small enough that the well licence application need not be denied because the well is a high-blowout-risk well.

20 If the well is drilled and an uncontrolled flow occurs, the well should be immediately ignited to convert the H_2S in the effluent to SO_2 which would be more widely dispersed. This action would significantly reduce the degree to which evacuations would be necessary.

21 Special ignition equipment and procedures proposed by Canterra would successfully ignite the effluent should a blowout occur.

22 If a partially controlled flow occurs at the proposed well but it is not completely out of control, the volume of gas being released is small, and human life is not being threatened, the operator would be given a time period to attempt to control the well prior to intentionally igniting it.

23 If the well is drilled, an emergency planning area with a radius of 8 km would be appropriate, but the area should be divided into three zones within which certain emergency actions would be required, depending on the zone.

24 Evacuation of residents should take place within 1 km of the well and sensitive individuals within 8 km of the well if a problem occurs during kick-control operations. Other residents within 4 km of

the well may, if they so desire, be voluntarily evacuated at the same stage; however, such evacuation would not be essential in terms of public safety.

25 A detailed emergency response plan is required and input from the public is essential during its preparation. The Board would be prepared to defray reasonable costs for an appropriate expert to advise the public of the Bergen area in this regard.

26 It is not appropriate prior to drilling a well to formulate plans for capping the well should a blowout occur; however, emergency planning with respect to the proposed well should be such as to ensure that control operations would be immediately commenced in the event of a blowout.

27 If the well proceeds and a blowout occurs, the impact of H_2S on the public would not be severe, provided the well is immediately ignited.

28 The SO_2 which would be emitted if the well blows out and is ignited would not have a significant impact on the surrounding area or its inhabitants.

29 A blowout at the proposed well would have little impact on surface or groundwater primarily because no condensate or liquid hydrocarbons are to be expected.

30 Late fall would be the time period during which a sour gas blowout at the proposed well would likely have the least impact on residents of the area. Adherence to a schedule that would accommodate that, in the unlikely event of a blowout, would not seriously delay the applicant in proceeding with the well.

31 The only particularly serious period at the proposed well would be while drilling in the critical zone when extra efforts are required to safeguard against a blowout. For this reason, efforts should be made to reduce the time period during which operations are taking place in the critical zone.

32 The applicant is a major, responsible Canadian corporation with very large resources and it undertook at the hearing to provide compensation for any damages it is responsible for. Consequently, there is not a specific need to require the posting of a performance bond or the carrying of special blowout insurance.

33 If the proposed well is drilled and a testing of the very sour zone is necessary, a separate application would be required. That application would have to detail procedures which would be used to minimize impacts of the tests on the public.

34 The successful drilling of the proposed well could lead to further developments in the area. These would be subject to further applications which would be considered on their merits at the time they are made.

14 DECISION

On the basis of the above listed findings, the Board concludes that the proposed well could be drilled without undue risk to the public, or impact upon it, provided the applicant implements drilling and emergency plans as discussed throughout this report. Many elements of Canterra's plans suitably provide for this, other areas require additional planning or modification, and the Board will condition the licence accordingly.

The Board is therefore prepared to issue the requested licence.

The following are the general areas where conditions will be applied:

1 Commencement of drilling will not be permitted if prior tests elsewhere in the province, of the proposed production technology, suggest little likelihood of it being successful.

2 Commencement of drilling will not be permitted until Canterra has submitted a final drilling program, which fully addresses, to the satisfaction of the Board, the areas identified in this report.

3 Drill-stem testing of the critical zone in the well will not be permitted unless a subsequent application demonstrates a clear need and that impacts on the public would be acceptable.

4 The operator will be required to provide daily reports of drilling progress, problems encountered, and other pertinent data to the Board's area office (Red Deer).

5 An uncontrolled flow at the well would require immediate ignition, and a partially controlled flow would only be allowed to continue without ignition where there is clearly no threat to human life.

6 Commencement of drilling will not be permitted until Canterra has submitted a final emergency response plan which fully addresses, to the satisfaction of the Board, the areas identified in this report.

7 The timing of and procedures used in the drilling of the well must be such that the time period during

which the critical zone is open would be minimized and limited to the months of October and November.

ISSUED at Calgary, Alberta, on 28 December 1984.

ENERGY RESOURCES CONSERVATION BOARD

G. J. DeSorcy, P.Eng.
Vice Chairman

C. J. Goodman, P.Eng.
Board Member

L. A. Bellows, P.Eng.
Board Member

APPENDIX 1 GLOSSARY OF TERMS

ABSOLUTE OPEN FLOW POTENTIAL (AOFP)	The rate at which the well would (AOFP) produce against a zero sandface back pressure. It cannot be measured directly but may be obtained from deliverability tests. It is often used by regulatory authorities as a guide in setting maximum allowable producing rates.
ANNULUS	The space between two concentric pieces of pipe or between a pipe and the hole in which it is located.
ANNULAR PREVENTER	See BLOWOUT PREVENTER.
BATTERY	In oil and gas production, a group of wells which flow to a common central facility where production can be measured and separated into oil, gas, and water.
BARITE PLUG	A high density, pumpable slurry consisting of barite, water, and thinner used to control underground blowouts where high pressure flow comes into the wellbore from a lower zone while losses occur into a higher but weaker zone or vice-versa.
BLOWOUT	The uncontrolled flow of gas, oil, or other well fluids into the atmosphere. An UNDERGROUND BLOWOUT occurs when the uncontrolled flow leaves one formation and enters a lower pressure formation.
BLOWOUT PREVENTER (BOP)	The valve-like equipment attached to the casing at a drilling rig to prevent a blowout. The BOP STACK is a combination of these valve-like devices, piping, and other fittings. The uppermost valve is generally the ANNULAR PREVENTER which forms a seal in the annular space between the pipe and wellbore, or if no pipe is present, on the wellbore itself. The BLIND RAMS are a closing element which seal upon each other when no drill pipe is present in the hole. The PIPE RAMS are a closing element which seal upon pipe in the hole, thereby closing the annular space between the pipe and the blowout preventer or wellhead. SHEAR RAMS are closing elements which can cut through or shear drill pipe and form a seal against well pressure.
BUBBLE POINT	The temperature and pressure at which part of a liquid begins to convert to gas.
CALIPER LOG	See LOG.
CASING	The steel pipe placed in a well to prevent the collapse of the hole and provide a conduit for fluids during the drilling and production phases. The SURFACE CASING is the first string of casing set in a well after the conductor pipe. Some regulatory bodies require a minimum length to protect fresh water sands. The INTERMEDIATE CASING is a string of casing set in a well after some period of drilling beneath the surface casing. Its purpose is to prevent the hole from caving and is therefore sometimes called PROTECTION CASING. The last string of casing generally set in a well is the PRODUCTION CASING, inside of which is usually

APPENDIX 1 (continued)

	suspended the TUBING STRING through which production takes place. The entire length of the joints of casing run in a well is referred to as a CASING STRING. Casing is manufactured in lengths or JOINTS of about 10 metres (m), each of which is joined together to form the string.
CASING PATCH (EXTERNAL)	A mechanical device used to form a permanent sealed connection between two strings of casing or tubing. Generally, the patch is run into the well on the end of the running string of casing or tubing and grapples and seals onto the cut-off string in the hole.
CASING PATCH (INTERNAL)	A steel liner which is placed opposite a damaged or perforated section of casing or tubing and expanded to seal against the casing or tubing walls thereby effectively closing off the perforations. Alternatively, a casing patch may be a short section of liner which is set across the perforated section of casing or tubing and fixed in place with packers at either end of the patch.
CASING TIE BACK	A string of casing which connects the top of the liner to the wellhead, thus isolating the production casing from production pressures. A tie-back string may also be used in the case of production or intermediate integrity problems, such as corrosion, in order to ensure wellbore integrity.
CEMENTING	This is an operation in which a liquid slurry of cement and water is applied to various points inside or outside of the casing. PRIMARY CEMENTING takes place immediately after the casing has been run into the hole and is used to provide a protective sheath around the casing as well as to segregate the producing formation and prevent migration of undesirable fluids. SECONDARY CEMENTING is any cementing operation following primary cementing. A CEMENT SQUEEZE is an example of secondary cementing in which a cement slurry is forced under pressure to specified points in a well. It is used to isolate a producing formation, seal off water, repair casing leaks, and so forth.
CHOKE MANIFOLD	The arrangement of piping and chokes through which drilling mud is circulated to control pressures encountered during a kick.
CIRCULATING	The pumping of drilling fluids down the drill pipe, out through the drilling bit, up the annulus, and back to the mud tanks.
CLEAN-UP	The flowing of a well following a stimulation during which the stimulating agent, such as acid, is removed from the well and collected. Gas is flared to atmosphere and liquid products and waste are collected in stock tanks for removal.
CLOBBERED MUD (OR CLABBERED)	A slang term commonly used to describe moderate to severe flocculation of drilling fluid due to various contaminants; also called "gelled-up".

APPENDIX 1 (continued)

CONDENSATE	A light hydrocarbon liquid obtained by condensation of hydrocarbon vapours. It consists of varying proportions of butane, propane, pentane, and heavier fractions with little or no ethane or methane.
CONDITIONING MUD	See MUD CONDITIONING.
CORING	A drilling operation utilizing a core barrel instead of a drilling bit in order to obtain a cylindrical sample of formation rock for geological analysis. The CORE BARREL is a tubular device run at the bottom of the drill pipe in place of a drill bit in order to cut a CORE SAMPLE.
CORE BARREL	See CORING.
CORE SAMPLE	See CORING.
CRITICAL SOUR WELL	For blowout prevention purposes, a critical sour well is defined as follows: (a) any proposed well from which the maximum potential hydrogen sulphide (H_2S) release rate is greater than 2.0 cubic metres per second (m^3/s), (b) any proposed well from which the maximum potential H_2S release rate is greater than 0.3 m^3/s and less than 2.0 m^3/s if the well is to be located within 5 kilometres (km) (3.1 miles) of an urban centre,* or (c) any proposed well from which the maximum potential release rate is greater than 0.01 m^3/s and less than 0.3 m^3/s if the well is to be located within 1.5 km (0.93 miles) of an urban centre, or (d) any other proposed well which the Board classified as acritical sour well having regard to the maximum potential H_2S release rate, the population density, the environment, the sensitivity of the area in which the well is to be located, and the expected complexities in the drilling of the well. * An urban centre is defined as a city, town, village, or other incorporated centre, and for the purpose of this directive includes any similar development the Board may designate as an urban centre.
CRITICAL ZONE	In drilling operations, the critical zone is a zone containing sour gas, generally the target formation. The ERCB's Draft Interim Directive – Blowout Prevention at Sour Wells addresses additional requirements while operations are taking place in the critical zone.
DEGASSER (POORBOY)	An open-bottomed steel vessel used to remove unwanted gas from a liquid, especially drilling fluid. The liquid enters the top of the vessel and passes down over a series of baffles which causes the entrained gas to break out of the liquid. The degassed liquid passes out of the bottom of the vessel

APPENDIX 1 (continued)

	into the mud tanks while the gas is vented from the top of the vessel to the flare pit where it is burned.
DRILL COLLARS	See DRILLING.
DRILL PIPE	See DRILLING.
DRILL-STEM TEST	The gathering of test data on a formation to determine its potential productivity. A drill-stem testing tool is lowered to bottom on the drill pipe and a packer is set which isolates the formation to be tested from the formation above. A port on the tool is opened to allow the trapped pressure below the packer to bleed off into the drill pipe, gradually exposing the formation to atmospheric pressure and allowing the well to produce to the surface, where the well fluids may be sampled and inspected. From the fluids produced and a record of the pressure readings, any number of facts about the formation may be determined.
DRILL STRING	See DRILLING.
DRILLER	See DRILLING.
DRILLER'S METHOD	One of several methods of well control used to circulate intrusive formation fluids or kicks out of the circulating mud system. This method of control may be used if the well can be closed in without exceeding the maximum allowable casing pressure (ie, the formation fracture pressure at the lowest depth at which casing is set). This method is advantageous in that it is simple, requires little calculation, and is effective under most conditions. In the first step, the original mud is pumped down the drill pipe at a constant pressure and the annulus is circulated free of invading fluids. If the hydrostatic pressure of the full column of drilling fluid does not overbalance the formation pressure, then a higher density drilling fluid is pumped into the well to replace the original, lower density drilling fluid.
DRILLING	The rotating of the DRILL STRING and bit and the circulation of DRILLING MUD to cause penetration of formations. DRILL STRING is a term often applied to the assembled lengths of DRILL PIPE and DRILL COLLARS. The DRILL PIPE is a heavy seamless pipe used to rotate the bit and through which the DRILLING FLUID or MUD is circulated. The DRILL COLLARS are heavier, thick-walled tube, usually steel, used between the DRILL PIPE and the bit in the DRILL STRING to place additional weight on the bit in order to improve its performance. The DRILLING MUD is the liquid circulated down the DRILL STRING and up the annulus during DRILLING. The procedure for DRILLING is laid out in a DRILLING PROGRAM prepared by the licensee of a well and containing instructions, diagrams, and other pertinent information. The employee directly in charge of a drilling or workover rig and crew is known as a DRILLER. His main duty is operation of the drilling and hoisting equipment but he is also responsible for the

APPENDIX 1 (continued)

	downhole condition of the well, operations of downhole tools, and pipe measurements.
DRILLING FLUID	See DRILLING, also see MUD.
DRILLING PROGRAM	See DRILLING.
DRILLING SPOOL	A spacer between components of the BOP stack, containing valved outlets.
EMBRITTLEMENT	The loss of a material's ductility, or ability to deform without fracturing. This is thought to be due to the absorption of hydrogen atoms into the material, usually in the presence of water and/or H_2S. Commonly referred to as HYDROGEN EMBRITTLEMENT, the various mechanisms include HYDROGEN INDUCED CRACKING (HIC), SULPHIDE STRESS CRACKING (SSC), and HYDROGEN BLISTERING.
FARM-IN	An agreement whereby the holder of a petroleum and natural gas lease permits another company to drill for and exploit petroleum and natural gas reserves under a number of specified conditions.
FLOW CHECK	A procedure carried out during drilling operations to confirm whether formation fluids are entering the wellbore. Generally, this involves observing to see whether the well is flowing on its own. Flow checks may be performed periodically or when any kick warning sign, such as gas-cut mud, is observed.
FLOW TOTALIZER	A device used to monitor the drilling fluid system and provide warning of potential blowout conditions either by an indication of a flowing well or of lost circulation.
FORMATION	A subsurface layer or deposit that is composed throughout of substantially the same kind of rock. The exerted pressure under which the formation splits is known as the FORMATION BREAKDOWN PRESSURE. The pressure required to break a formation must exceed the pressure exerted by the overlying rock. Fluids trapped within the pore space of the formation are also under pressure due to the overlying rock (or previously overlying rock). This pressure divided by the depth of the formation gives the FORMATION PRESSURE GRADIENT. A NORMAL GRADIENT is the pressure gradient of a column of salt water and ranges between 9 and 11 kilopascals per metre (kPa/m). An ABNORMAL or OVERPRESSURED FORMATION will have a gradient in the range of 11 to 16 kPa/m. A SUBNORMAL or UNDERPRESSURED FORMATION will have a gradient in the range of 5 to 9 kPa/m.
FORMATION BREAKDOWN PRESSURE	See FORMATION.
FORMATION, NORMAL	See FORMATION.
FORMATION, OVERPRESSURED	See FORMATION.
FORMATION PRESSURE GRADIENT	See FORMATION.

APPENDIX 1 (continued)

FORMATION, UNDERPRESSURED	See FORMATION.
GAS PLANT	An installation in which natural gas is processed to prepare it for sale to consumers. A gas plant separates desirable hydrocarbon components from the impurities in natural gas.
H_2S SCAVENGER	A material that deactivates any H_2S entering the wellbore.
H_2S TRIM	A general term used to indicate that a piece of equipment, which may be exposed to H_2S gas, is fabricated from H_2S resistant material.
HYDROSTATIC PRESSURE	The pressure exerted by a column of fluid such as the drilling mud in the wellbore.
ISOPLETH	An imaginary line surrounding a point of potential contaminant release, formed by joining points which under certain conditions and at different times could experience an equal contaminant concentration (similar to a contour line).
KICK	Any entry of water, gas, oil, or other formation fluid into the wellbore. It occurs because the pressure exerted by the column of drilling fluid is not great enough to overcome the pressure exerted by the fluids in the formation drilled. If prompt action is not taken to control the kick or kill the well, a blowout will occur.
KICK CONTROL	Procedures used to control and eventually prevent further influx of formation fluids into the wellbore, thereby preventing a potential blowout. Formation fluids that have entered the wellbore are removed and replaced with an uncontaminated mud of a suitable density. Examples of these procedures are the Driller's Method, the Wait and Weight Method, and the Concurrent Method.
KILL	Activities to stop or to prevent the threatened blowout of a well. Usually accomplished by the injection of dense fluid into the well. A TOP KILL refers to the pumping of high density mud down a wellbore without drill pipe in the hole.
KILL, TOP	See KILL.
LOG	A systematic recording of data, as from the driller's log, mud log, electric well log, or radioactivity log. Many different logs are run in wells being produced or drilled to obtain various characteristics of downhole formations. A CALIPER LOG is a record whereby the diameter of the wellbore is ascertained indicating undue enlargement due to caving in, washout, or other causes. The caliper log also reveals corrosion, scaling, or pitting inside tubular goods. A MUD LOG is a record of information derived from examination of drilling fluid and drill cuttings. A portion of the mud is circulated out of the hole past a gas detecting device and is also examined under ultraviolet light to detect the presence of oil or gas. The MUD LOGGER is the employee of the mud-logging company who keeps the mud log.

APPENDIX 1 (continued)

LOG, CALIPER	See LOG.
LOG, MUD	See LOG.
LOGGER, MUD	See LOG.
LOST CIRCULATION	The loss of drilling fluid from the wellbore into a very permeable formation.
MANIFOLD	See CHOKE MANIFOLD.
MUD	The liquid circulated down the drill pipe and up the annulus during drilling.
MUD, CLOBBERED	See CLOBBERED MUD.
MUD CONDITIONING	The treatment of drilling mud with additives to give to certain properties. To condition and circulate mud is to ensure that additives are distributed evenly throughout a system by circulating the mud while it is being conditioned.
MUD, DRILLING	See MUD, also see DRILLING MUD.
MUD LOGGER	See MUD.
MUD PILL	A small quantity of heavy drilling fluid pumped into the top section of drill pipe prior to pulling the drill pipe out of the hole. This permits the mud level inside the drill pipe to fall, permitting connections to be broken without mud inside the drill pipe at floor level. (Also known as "slugging the pipe" or a "dry trip".)
MUD, WEIGHTING-UP	The addition of materials with a high specific gravity to a drilling fluid in order to increase its density. This material is commonly barite, but may also be galena or limestone.
PARTIAL PRESSURE	The pressure exerted by one component of a gas mixture. The total pressure is the sum of the partial pressures of the individual components of the gas mixture, each considered as if it were the only gas present in the given volume.
PERMEABILITY	A measure of the ability of fluids to flow through rock.
PIPE RAMS	See BLOWOUT PREVENTER.
pH	The acidity or alkalinity of a fluid; a measure of hydrogen ion activity.
POROSITY	The void or open space in a rock.
POSITIVE PRESSURE AIR SUPPLY	A system used in the design of a breathing apparatus whereby the face mask is provided with an air supply of greater pressure than atmospheric pressure, to prevent infiltration into the mask of potentially harmful gases.
PRODUCTIVITY INDEX (PI)	A well-test measurement indicative of the amount of oil or gas a well is capable of producing.
RAW GAS	Naturally occurring gas prior to the removal of unwanted impurities at a gas plant.

APPENDIX 1 (continued)

RELIEF WELL	A well drilled near and deflected into a well that is out of control, making it possible to bring the wild well under control.
SEMI-DISPERSED	The condition in which the material or phase to be scattered or dispersed in a continuous or surrounding phase has not yet been completely dispersed.
SHEAR RAMS	See BLOWOUT PREVENTER.
SHUT IN	To close the valves on a well so that it stops producing or to close in a well in which a kick has occurred.
SKIN DAMAGE (SKIN EFFECT)	1. The area of the formation that is damaged because of the invasion of foreign substances into the exposed section of the formation adjacent to the wellbore during drilling and completion. 2. The pressure drop from the outer limits of drainage to the wellbore caused by the relatively thin veneer (or skin) of the affected formation. Skin is expressed in dimensionless units; a positive value denotes formation damage and a negative value indicates improvement.
SPOOL	See DRILLING SPOOL.
SPUD	To start drilling the wellbore.
STRIP INTO	The lowering of pipe, tubing, or coiled tubing into a well under pressure. In the case of a blowout, once the pipe is in the hole the well can be routinely killed using conventional procedures.
SUPERCRITICAL GAS	A dense phase vapour occurring at specific temperatures and pressures.
SWABBING	To cause a sucking action within the wellbore by pulling the drill pipe up the wellbore too quickly and accelerating or inducing the invasion of formation fluids.
TIE BACK	See CASING TIE BACK.
TOOLPUSH	A drilling foreman or rig superintendent.
TRIP	The process of pulling the drill string out of the hole or TRIP OUT, to change a drill bit or other bottom-hole equipment, and then lowering the drill string back into the hole or TRIP IN.
TRIP IN	See TRIP.
TRIP OUT	See TRIP.
TRIP TANK	A small calibrated mud pit used exclusively to ascertain the amount of mud necessary to keep the wellbore full with the exact amount displaced by drill pipe being removed.
TUBING	Small diameter pipe that is run into a well to serve as a conduit for the passage of oil and gas to the surface.

APPENDIX 1 (continued)

TUBULAR GOODS	Any kind of pipe; also called tubular. Oil-field tubular goods include tubing casing, drill pipe, and line pipe.
TUBULARS	See TUBULAR GOODS.
UNDERGROUND BLOWOUT	See BLOWOUT.
VISCOSITY	A measure of the resistance of a liquid to flow. The viscosity of petroleum products is commonly expressed in terms of the time required for a specific volume of the liquid to flow through an orifice of a specific size.
WELL EFFLUENT	The substances which flow out from a well.
WELLHEAD	The equipment used to maintain surface control of a well after it has been drilled and completed.

APPENDIX 2

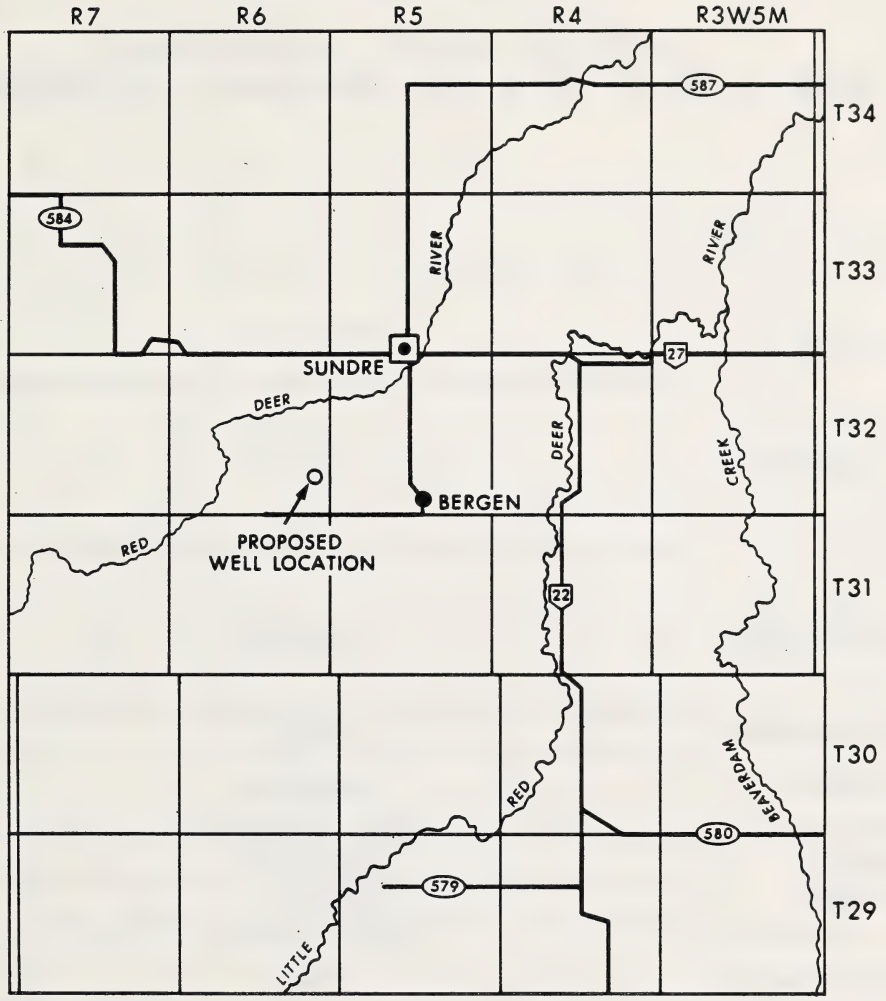


FIGURE 1 CANTERRA'S PROPOSED CAROLINE WELL IN THE SUNDRE - BERGEN AREA.

APPENDIX 3

GEOLOGICAL CROSS-SECTION
PROPOSED CANTERRA WELL 12-12-32-6 W5M

DEPTH		
1446	BELLY RIVER	SAND / SHALE
1726	WAPIABI	SANDSTONE / SILTSTONE
2302	CARDIUM	SANDSTONE / SILTSTONE
2778	VIKING	SANDSTONE / SILTSTONE
2846	BLAIRMORE	SANDSTONE
3069	MANNVILLE GROUP	SANDSTONE
3172	ROCK CREEK	SANDSTONE
3187	NORDEGG	LIMESTONE
3206	RUNDLE GROUP	DOLOMITE / LIMESTONE
3322	BANFF	LIMESTONE / SHALE
3522	WABAMUN	DOLOMITE / LIMESTONE
3798	NISKU	DOLOMITE
3853	IRETON	SHALE
3887	LEDUC	DOLOMITE
4087	COOKING LAKE	DOLOMITE / LIMESTONE
4137	BEAVERHILL LAKE	DOLOMITE / LIMESTONE
4237	ELK POINT	SHALE
4257	CAMBRIAN	DOLOMITE
TD – 4287		

APPENDIX 4

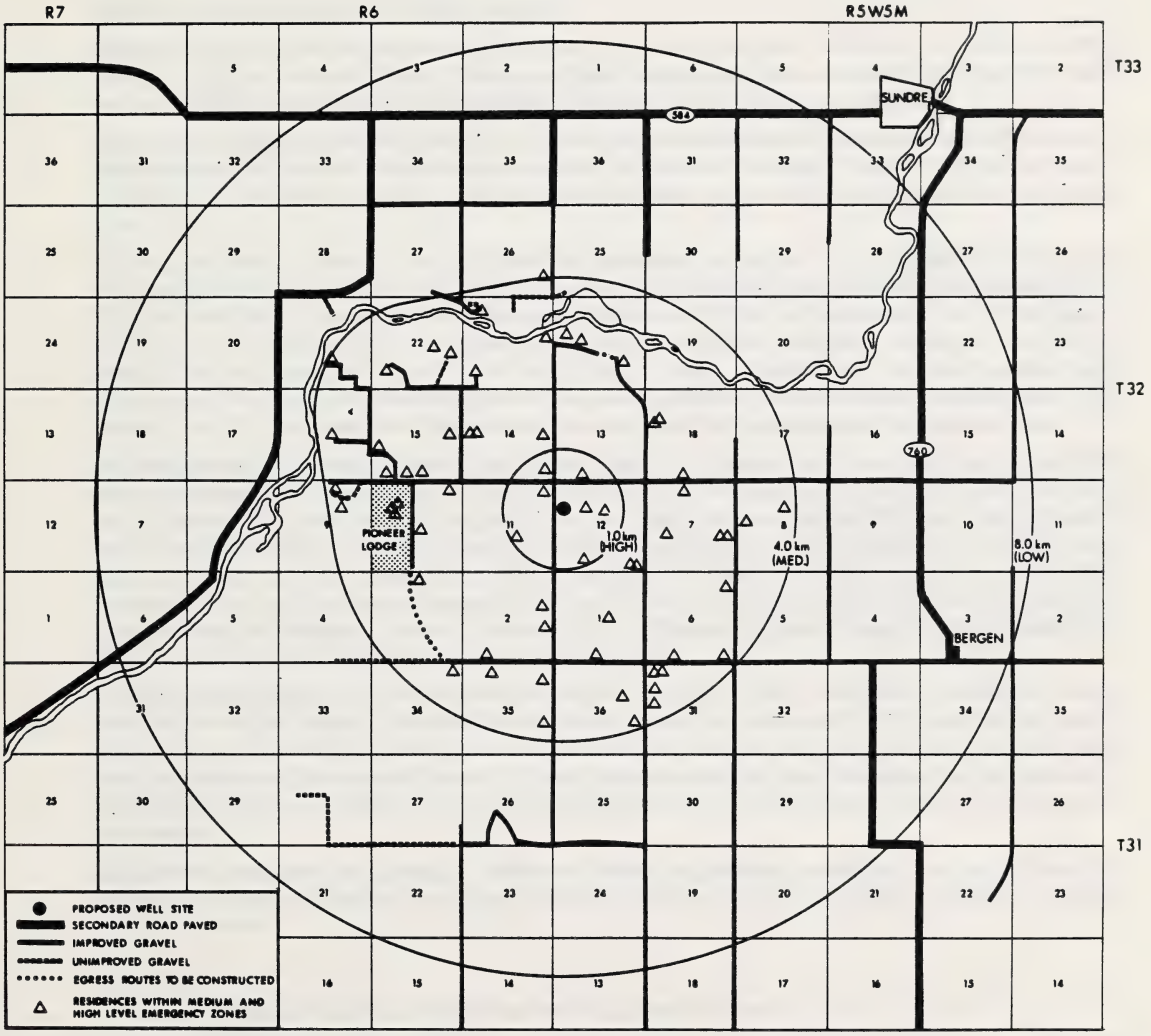


FIGURE 2 PROPOSED CANTERRA CAROLINE WELL IN THE SUNDRE AREA
Adapted from Appendix D, Canterra Caroline 12-12-32-6 W5M
Revised Emergency Alert and Evacuation Plan.

APPENDIX 5 DRAFT INTERIM DIRECTIVE ID 84-

To: All Operators, All Drilling Contractors,
and the General Public

BLOWOUT PREVENTION AT SOUR WELLS

Reference is made to the recently completed inquiry respecting the 1982 blowout at the AMOCO DOME BRAZEAU RIVER 13-12-48-12 well. The second phase of that inquiry was not related to the specific blowout but dealt with the broad subject of the prevention of blowouts in the Province as a whole.

There was considerable agreement among most participants on a number of the matters dealt with. One such matter related to the need for special safeguards against blowouts in the drilling of certain "critical sour wells" Discussion also took place respecting plans that would minimize impacts on the public should such a blowout occur.

The Board believes this matter to be of considerable importance and urgency and consequently is issuing this draft Interim Directive to define certain wells it considers to be "critical" and to establish requirements for the drilling of those wells. It recognizes that the special requirements will result in somewhat higher drilling costs for these wells but is convinced that these additional costs are warranted particularly having in mind that the potential cost of a blowout at one of these wells is very large. It should also be noted that the special requirements and related costs would apply only to a small portion of the total number of wells drilled in the Province. In 1983, fewer than 50 of the wells drilled would have been designated as "critical sour wells".

The Board intends that these interim requirements will apply for an approximate 6-month period, during which time the adequacy of them will be tested. Comments with respect to these requirements are invited prior to the end of October 1984, from industry, the public, and any other interested parties. The Board would expect to issue a new directive and, as necessary, amend the regulations at the end of the trial period, thus establishing a long-term policy respecting critical sour wells. At that time the Board will review and update, and combine where appropriate, its directives with respect to sour gas. (Interim Directive ID-OG-76-2, Emergency Procedure Plans For Sour Gas Facilities. Interim Directive ID 81-3, Minimum Distance Requirements Separating New Sour Gas Facilities From Residential and Other Developments.)

This draft Interim Directive is being included in the Phase 2 inquiry report. A task force or committee is being established to review certain of the matters discussed at Phase 2 of the inquiry. The Board believes that the committee should review the appropriateness of this draft directive and the policy it establishes, and should provide its comments by the end of October. If in the meantime and as a result of applying the requirements on an interim basis, particular problems or questions arise, the Board will refer such questions to the committee for its comments.

This interim policy does not change the minimum distance requirements separating sour gas facilities from residential and other developments as set out in Interim Directive ID 81-3. The policy respecting critical sour wells is as follows:

Definition

For blowout prevention purposes a critical sour well is defined as follows:

(a) any proposed well from which the maximum potential hydrogen sulphide (H_2S) release rate is greater than 2.0 cubic metres per second (m^3/sec),

(b) any proposed well from which the maximum potential H_2S release rate is greater than 0.3 m^3/sec and less than 2.0 m^3/sec if the well is to be located within 5 kilometres (3.1 miles) of an urban centre*, or

(c) any proposed well from which the maximum potential release rate is greater than 0.01 m^3/sec and less than 0.3 m^3/sec if the well is to be located within 1.5 kilometres (0.93 miles) of an urban centre, or

* An urban centre is defined as a city, town, village, or other incorporated centre, and for the purpose of this directive includes any similar development the Board may designate as an urban centre.

APPENDIX 5 (continued)

(d) any other proposed well which the Board classifies as a critical sour well having regard to the maximum potential H_2S release rate, the population density, the environment, the sensitivity of the area in which the well is to be located, and the expected complexities in the drilling of the well.

Special Requirements

The applicant for a licence for a critical sour well must satisfy the following special requirements:

1 A satisfactory emergency response plan must be filed with the Board prior to the spudding of the well. The plan must meet the minimum content requirements set out in ID-OG-76-2 and must describe the manner in which the public would be notified, have their safety protected, and be evacuated if necessary, in the event of a blowout. The plan must also have been discussed with members of the rural public and urban representatives that reside within the maximum 100 parts per million isopleth which could be associated with the well. It should also deal with the manner in which the decision would be made as to whether the well would be intentionally ignited in case of a blowout.

This requirement for an emergency response plan is in addition to those set out in ID-OG-76-2 for gas plants and pipelines. Also, pursuant to section 7.060 of the Oil and Gas Conservation Regulations, the Board may continue to request emergency response plans for certain wells which are not "critical sour wells" under this directive.

2 A general description of the drilling plan and the equipment to be used to drill the well must be submitted to and approved by the Board prior to the spudding of the well. The plan would include geological data as necessary but be general in nature and briefly describe any serious drilling problems which may be expected and the manner in which they would be handled. It should also briefly address critical equipment such as the BOPs (including a discussion as to whether or not shear rams will be installed), the drill string, the degasser, the mud system, and procedures, to ensure that all such equipment is fully operative prior to penetrating the critical zone. The plan should also provide for the taking of a directional survey unless the operator can satisfy the Board that it is not needed.

3 The operator must satisfy the Board prior to spudding that supervision during the drilling of the well will be adequate. This will require on-site supervisors with Level 2 certification and some experience in drilling in sour areas. During critical periods at the well, such as drilling into the sour formation, sufficient supervision must be available so that no individual supervisor is required to work a shift longer than 12 hours.

4 The operator must satsify the Board prior to spudding that the drilling crew and key service personnel on the rig are adequate in number and sufficiently qualified. A minimum 5-man drilling crew will normally be required and at least some of the personnel should have experience in sour areas.

5 The operator must satisfy the Board prior to spudding that adequate safety personnel and safety equipment for workers will be on site at all critical times.

6 Intermediate casing set to an appropriate point above the zone from which sour gas or oil is expected will normally be required. However, the Board may exempt certain wells from this requirement if the applicant can demonstrate with a high degree of certainty that intermediate casing is not warranted.

7 A complete inspection and blowout prevention drill will be required prior to drilling out the surface casing and the intermediate casing and before penetrating the formation expected to contain sour gas. The Board field office must be notified at least 48 hours ahead of time so that staff may participate if judged appropriate.

8 If the well is not abandoned, completion and servicing operations will not be permitted without prior consent from the Board. Consent will be granted only if the Board is satisfied that proper equipment and trained personnel will be used and that adequate precautions to prevent a blowout will be taken.

APPENDIX 5 (continued)

Additional Information to
Support Well Licence Applications

The maximum potential H_2S release rate must be submitted as part of a licence application for any well and should be calculated on the basis of the maximum flow rate and H_2S content which can be expected. It should reflect all information available from wells in the area and a realistic engineering approach which recognizes the expected geological setting and reservoir fluid. A detailed description of the type of information required is set out in Attachment I.

Information respecting the maximum potential release rate along with plans for satisfying the above special requirements should be submitted with a licence application for any well which would be a "critical sour well" in accordance with the definition in this directive. In instances where the Board decides that a critical designation should be attached to a well which does not otherwise qualify in accordance with this directive, the applicant for a licence will be sent a deficiency letter requesting information to satisfy the special requirements.

The additional information provided the Board to determine the maximum potential H_2S release rate or to satisfy the above listed special requirements will, with certain exceptions, be considered as public information. Where geological data or personal information respecting individuals is provided as part of the submission, the Board will, upon request from the applicant, consider it as confidential. Such information should be included in a separate volume to avoid inadvertant release. In situations where a well licence application goes to a public hearing the matter can be decided on the basis of only that information which is public. However, the applicant will be provided with an opportunity to reclassify as public, all or a modified part of the data originally filed as confidential.

Comments regarding this directive from industry, the public, or other interested parties should be addressed to the Manager, Development Department (297-8169).

Applicants requiring further information regarding well licensing should address their inquiries to the Well Licensing Section (297-8159) and regarding emergency response plans to the Environment Protection Department (297-8324).

ISSUED at Calgary, Alberta on 25 April 1984.

Vernon Millard
Chairman

Attachment

ATTACHMENT I (ID 84-)

Where an application is made to the Board for a well licence, the applicant shall include in the application the information required in either A or B, as applicable.

A A statement and supporting evidence to the effect that none of the formations to be encountered during the drilling of the well are expected to contain hydrogen sulphide (H_2S).

or

B 1. For each formation to be penetrated which may contain H_2S:

(a) the maximum expected concentration of H_2S, and the source of this information,

(b) the maximum expected flow capability at the surface for the case where the unstimulated formation is open to the wellbore as during drilling, and for the case where the well has been completed and the formation stimulated, and the method and information used to determine these values,

(c) the calculated potential H_2S release rate expressed in the units of cubic metres per second for each of the two cases referred to in (b) above.

2. The maximum potential uncontrolled release rate of H_2S at the stage in the drilling of the well where the sum of the release rates from each formation open to the wellbore is a maximum.

3. The maximum potential uncontrolled release rate of H_2S during the producing stage for the well.

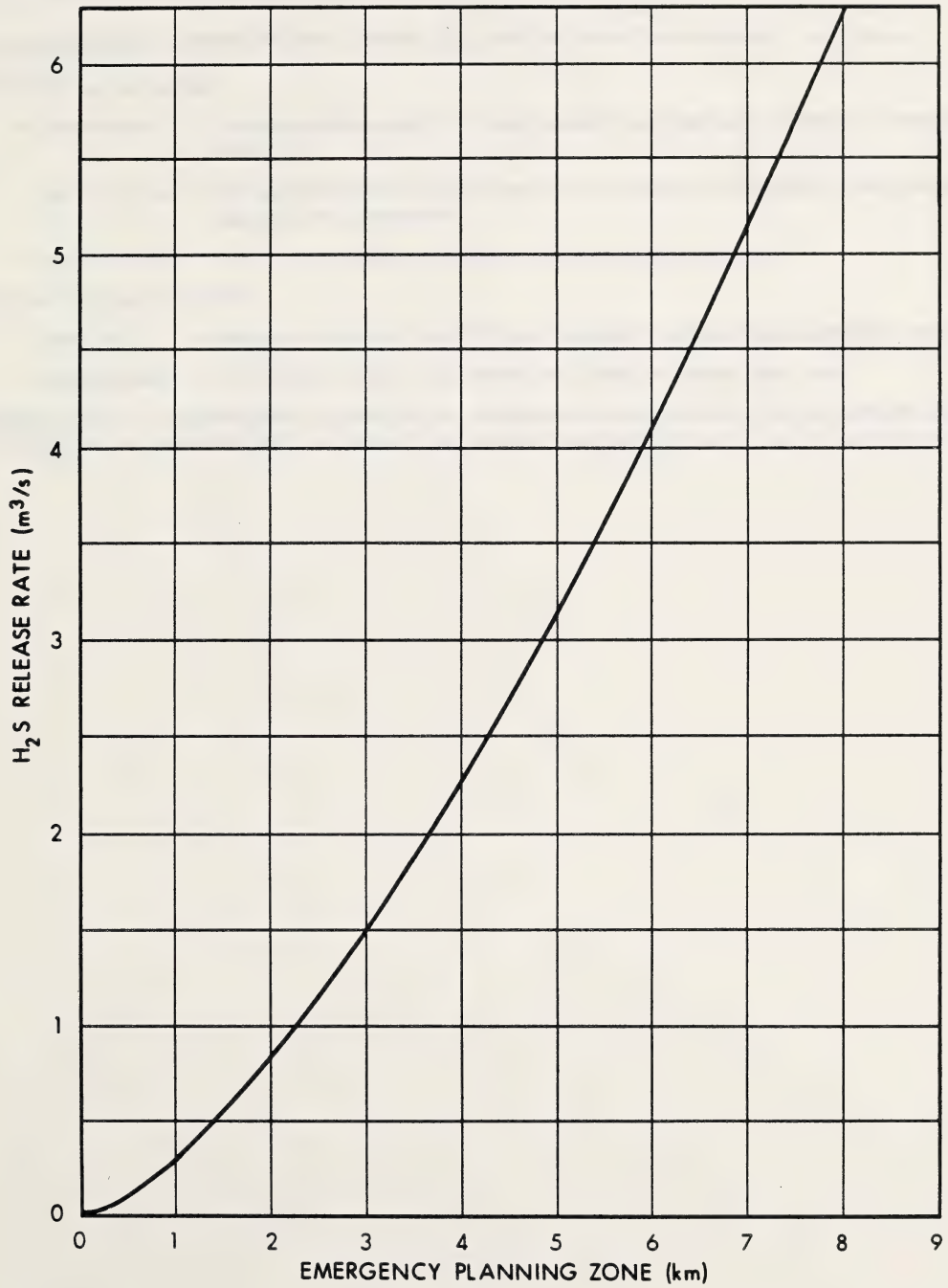
4. The radius of the emergency planning zone for each of 2 and 3 above, determined from the graph in Figure 1 to this Attachment.

5. A map showing the location of all residences and public facilities located within the larger of the emergency planning zones.

6. A statement of the distance to the nearest permanent residence, public facility, rural subdivision, or urban centre beyond the larger of the emergency planning zones, plus an indication of the population density in the general area beyond the planning zone a distance approximately equal to the radius of the planning zone.

It is emphasized that a realistic, responsible engineering approach must be taken. The expected geological setting and reservoir fluids to be encountered must be recognized along with all relevant tests and analyses for the area. In order that the best possible information be available all operators are urged to file the results of tests and analyses with the Board as soon as possible following the completion of the tests.

FIGURE 1 TO ATTACHMENT 1
EMERGENCY PLANNING ZONES FOR SOUR GAS WELLS



APPENDIX 6 IGNITION CRITERIA

Uncontrolled Flow – unrestricted flow at surface that cannot be shut off at the operator's discretion, eg,

With drill pipe in the hole

- open annulus – flow up the annulus with BOP stack inoperative and pipe rams and annular preventer essentially open
- open drill pipe – flow up the drill pipe with stabbing valve not installed or inoperative in the open position and shear ram inoperative
- material failure – flow through cracks, seals, gaskets below the lowest pipe rams

With no drill pipe in the hole

- open well – flow up the wellbore with BOP stack inoperative and blind rams essentially open
- material failure – flow through cracks, seals, gaskets, etc, below the lowest blind rams

Partial Control – a restricted flow at surface of low volume which cannot be shut off at the operator's discretion but which can be approached safely by workers using suitable breathing apparatus, or can be safely flared.

N.L.C. - B.N.C.
3 3286 05629124 4